New Scientist

WEEKLY 21 August 2021

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Big Thinkers series

This series of talks features experts on some of the most fascinating topics in science, from Anil Seth on consciousness to Michelle Simmons on quantum computing. Join us live as we journey to the frontiers of knowledge, or watch on demand, with seven of the talks available to stream now.

The science of can and can't

Most physics theories describe reality by predicting what will happen. But there is another way to explain things: find the rules that say what is possible and what isn't. In this talk, Chiara Marletto discusses this revolutionary approach. Join us on 2 September from 6pm BST. Tickets available now.

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Podcasts

Weekly

Tamsin Edwards, an author of the latest Intergovernmental Panel on Climate Change report, joins the team for a special episode. Media coverage of the report has left many concerned, so we take time to unpack the findings and focus on the points of hope and action. Also featured this week is the precision fermentation technology being used to create guilt-free milk, cheese and ice cream. Plus, we hear of a killer tobacco plant that could be a natural pest control solution.

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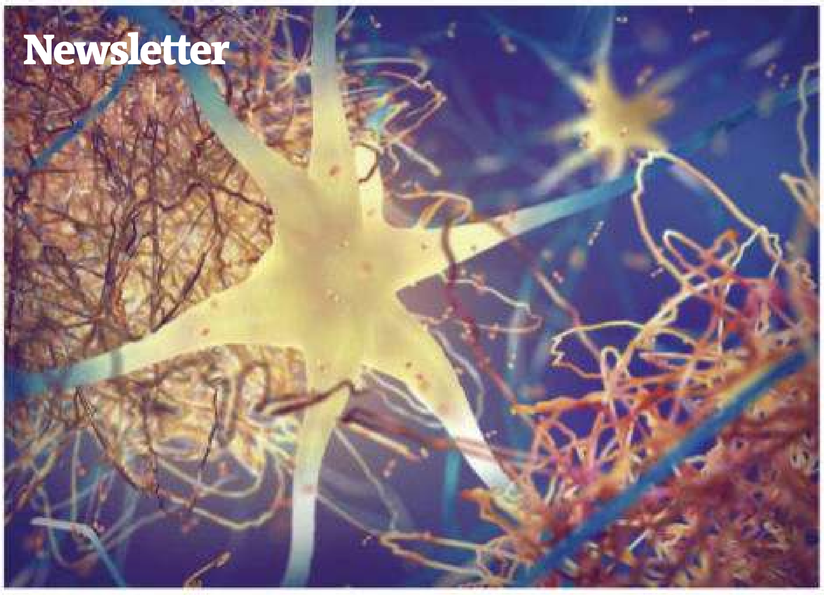

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In a tangle We are still unsure of what causes Alzheimer's in the brain

PERFECT DAY

Guilt-free treats Milk for ice cream can be made without animals

Video

Ocean Witness

Operation Ocean Witness is a Greenpeace campaign fighting to stop destructive fishing in protected marine areas off the coast of England. *New Scientist* spent a day on patrol with the team to find out more. There is plenty more science, discovery and innovation on our channel, plus our unmissable explainer series, Science with Sam.

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Newsletter

Health Check

Get reporter Clare Wilson's weekly must-read newsletter on health and fitness delivered free to your inbox. The most recent edition looks at early, AI-powered diagnosis of Alzheimer's disease – and why much of the research on this disease may have been misdirected.

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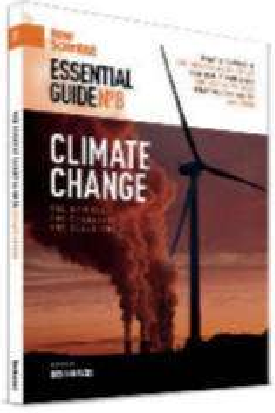
Newsletter

> **"Most research efforts to treat Alzheimer's over the past three decades may have been misdirected"**



Essential guide

Climate change is the greatest challenge humans have ever faced. The eighth in our series of *Essential Guides* explains everything you need to know, from basic climate science to the technologies we will need to reach net-zero emissions.

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AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

Right now, the Foundation is funding research to tackle antimicrobial resistance, and investing in researchers like Dr Myrsini Kaforou – who will make the fight against antimicrobial resistance her life's work.

Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

> "As scientists, our duty is to secure the future of research for the generations that follow."
>
> Professor Fiona Watt, President of the Medical Research Foundation and Executive Chair of the Medical Research Council.

Your Will can fund the rational response to health challenges that medical science provides.

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"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

Please consider this very special gift today.

Professor Nick Lemoine MD PhD FMedSci
Chair of the Medical Research Foundation

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Arabian insights

Stunning finds have thrust the region into the story of humanity's rise

THE tale of human origins continues to throw up surprises. For many years, the generally accepted narrative was that our species emerged on the continent of Africa, before spreading to other continents around 60,000 years ago. It is certainly true that our origins lie primarily in Africa. But in this issue, we explore the crucial role that nearby Arabia played in human evolution (see page 36).

Evidence unearthed in Stone Age Arabia points to a much richer story, in which human populations ebbed and flowed in this region over hundreds of thousands of years as the climate shifted.

The remarkable discoveries from Arabia remind us that, when it comes to the study of human evolution, much of the planet is yet to be explored. The systematic study of Arabian prehistory is barely more than a decade old. Many of the researchers who work there were told not to bother because "there was no prehistory in Arabia" and were even laughed at.

Those researchers are getting the last laugh. As the feature explains, it turns out there is an enormous amount of prehistory in Arabia: there are dozens of archaeological sites, often with rich collections of artefacts, that date back 500,000 years and perhaps further.

> "When it comes to the study of our evolution, much of the planet is yet to be explored"

Some parts of the world have been thoroughly studied for hominin remains, such as east Africa and western Europe. But there are many more places like Arabia that are seriously underexplored. India is one such location, and even less is known from central Asian nations like Kyrgyzstan.

Even in Africa, for so long considered the only cradle of humanity, exploration has been largely focused on the east and south. Those places have yielded spectacular discoveries, but in recent years some anthropologists have begun paying more attention to the previously neglected north and west – sometimes making incredible finds, like the oldest known members of our species that were identified in Morocco in 2017.

The more we step past our preconceptions about where our ancestors lived, the more we will find – and the deeper our understanding of our origins will become. ▮

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CONTACT US

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General & media enquiries
UK **Tel**+44 (0)20 7611 1200
Northcliffe House, 2 Derry Street, London, W8 5TT
Australia 418A Elizabeth St, Surry Hills, NSW 2010
US PO Box 80247, Portland, OR 97280
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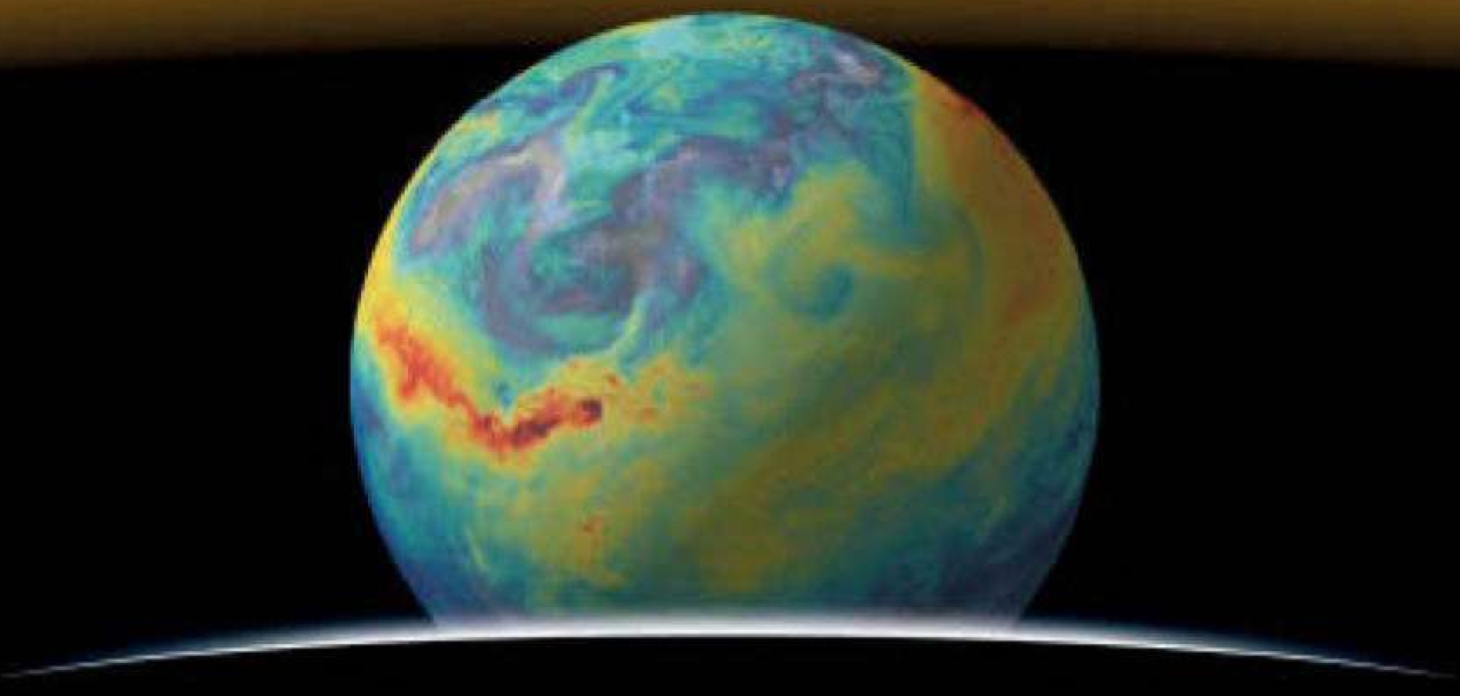

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JAMES D. MORGAN/GETTY IMAGES

Sydney remains under a strict lockdown

Coronavirus

Australia's delta wave

The country's strict covid-19 measures haven't been enough to stop the extremely contagious variant, reports **Alice Klein**

IN SYDNEY, the pandemic feels like it is just getting started. The city is battling its worst covid-19 outbreak yet, which is being blamed on the highly contagious delta coronavirus variant and low vaccination rates.

Since early in the pandemic, Australia has tried to keep the coronavirus out altogether by banning international visitors, quarantining all Australians returning from overseas and rapidly locking down whenever covid-19 is detected in the community.

This worked for a long period. For example, in the first half of 2021, the country didn't record a single death from locally acquired covid-19.

Then the delta variant arrived. A Sydney limousine driver who transported international aircrew was infected in mid-June, prompting stay-at-home orders to be introduced across greater Sydney on 26 June. The lockdown there is now in its eighth week – people can only leave home for reasons like buying food and essential work – but covid-19 cases and deaths are climbing.

Over 400 covid-19 cases are now being recorded daily in Sydney and the rest of the state of New South Wales. Eight deaths from the virus were recorded in the state on 15 August – its highest daily toll of the pandemic so far. In addition, the virus has started to spread into other Australian states and territories.

There are several reasons why case numbers aren't going down this time, even though the same strategies that successfully contained previous outbreaks have been deployed, say experts.

One is the greater transmissibility of the delta variant, says Catherine Bennett at Deakin University in Melbourne. "Now, if the virus gets into a household, everyone gets infected, whereas last year probably only a third of people would," she says.

The extreme contagiousness of the delta variant was highlighted when 45 of 50 people who attended a funeral in Sydney that breached the 10-person limit were infected with the virus.

The shorter incubation time of the delta variant is also making it harder for contact tracers to identify and isolate potentially infectious people before they can pass the virus on, says Bennett.

Finally, the virus has found its way into parts of Sydney that are home to high concentrations of people who are unable to work from home, says Angela Webster at the University of Sydney. "They are doing caring work, warehouse work, cleaning, driving – things that are absolutely essential," she says. The virus is spreading through workplaces, households and supermarkets in these areas, but "you can't stop people doing essential work, living together or buying food", says Webster.

Since it is looking unlikely that Sydney will be able to contain this outbreak with lockdown measures alone, it is "now a race to vaccinate", says Webster. Only 26 per cent of people aged over 16 in Australia are fully vaccinated.

Australian government modelling suggests that lockdowns will no longer be necessary when 80 per cent of adults are fully vaccinated – a target it hopes to hit by the end of the year. Webster believes people in Sydney probably won't be able to socialise in large groups or go to restaurants until next year. "Everyone here is very doom and gloom," she says, "but we are averting thousands of deaths with this lockdown and we know the vaccine will end it."

Meanwhile, New Zealand, which has also used strict measures to largely keep the virus under control there, brought in a nationwide three-day lockdown on Tuesday following the detection of a new covid-19 case in Auckland. ▮

Climate change

Will the IPCC report matter?

It is clear that we must move quickly to avoid the worst of climate change, but will the latest IPCC report finally push politicians to act, asks **Adam Vaughan**

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Climate activists at a protest in Berlin, Germany, on 12 May

WORLD leaders must drastically scale up their plans to curb carbon dioxide emissions if humanity is to avoid the worst consequences of a warming world outlined in last week's report by the Intergovernmental Panel on Climate Change (IPCC). Unfortunately, there is no sign of that happening yet, but observers say the publication should boost political action on emissions.

The report, coupled with recent extreme weather events such as Greece's wildfires and a record 48.8°C temperature in Europe, has been seen by many as a wake-up call that should galvanise societies to take action.

Environmental leaders have called for new versions of the climate plans that countries are meant to submit every five years as part of the 2015 Paris Agreement's framework. Without stronger plans, "the Paris Agreement goals will be out of reach", tweeted Patricia Espinosa at United Nations Climate Change, the body that oversees international climate talks, which will reach a crunch moment at the COP26 summit in Glasgow, UK, this November.

Nations' current plans are estimated to put the world around the middle of the five emissions scenarios considered in the IPCC report. This would see Earth warm by 2.7°C by the end of the century – well above the 1.5°C and 2°C goals of the Paris Agreement.

COP26 president Alok Sharma has asked countries to produce bolder plans before the meeting. Last week, he called for "major emitters to play their part", a phrase that is typically used to refer to China, the US, the European Union and India, which together account for more than half of global emissions. In response to the IPCC report, China gave no hint that a new plan is in the works, instead referring back to its existing long-term plan of carbon neutrality by 2060.

Nonetheless, the IPCC's work should give a boost to COP26 and politicians who are in favour of climate action. "I think the IPCC report is a massive wake-up call," says Peter Betts, a former lead EU negotiator on climate and now an associate fellow at UK think tank Chatham House. "Coupled with these extreme weather events, I think this does reinforce the politics for action."

> **"People are joining the dots that climate change is here and it's having nasty impacts"**

Most high-income nations have already upgraded their plans from their 2015 versions, so there is little hope for more action from them. In April, the US pledged a 50 per cent cut in CO_2 emissions by 2050 and the EU committed to a 55 per cent reduction in the same period. "You've got pledges of action from all the big developed countries, apart from Australia, which are at the very top of what we thought possible a year ago," says Betts.

This means that the lion's share of the gap between government pledges today and the action needed to meet the Paris Agreement's goals must be closed by middle-income nations, says Betts. That doesn't seem to be happening. "You've got some big emerging economies like Brazil and Indonesia basically not moving, or even going backwards, so this is a problem," he says.

Whether a strong new plan is forthcoming from China, which emits more than a quarter of the world's CO_2 and currently only plans to peak CO_2 emissions by 2030, will be crucial. "My guess is they will revise it. The question is, will they do something incremental that looks good or something transformational? You can construct a powerful set of reasons why it [China] will do something ambitious, and why it might do something incremental," says Betts.

The IPCC report may help bolster the case for other governments too, even if they stop shy of a new climate plan. India, for example, was thought to be on the brink of issuing a net-zero goal ahead of US president Joe Biden's climate summit in April, but failed to do so. We also know that South Korea, the world's 11th-biggest CO_2 emitter, is working on a new plan.

The biggest political consequence of the IPCC report may simply be to put the issue back at the top of the agenda for governments distracted by the pandemic, economic problems and other pressing domestic concerns. "Leaders have an enormous number of issues on their plate every day, covid being the obvious one. This issue struggles to get to be the number one priority," says a UK government source.

Referring to the IPCC report, the source says: "It just moves the issue up front and centre.

It can [sometimes] be perceived as a longer-term agenda, or an agenda [only] for the heaviest-emitting countries or those already feeling the most impacts. The message [from the IPCC] is that it's global and requires a global solution. This sets out very starkly for every world leader that this has got to be at the top of their inbox from now right through to Glasgow, so big enough decisions can be made to avert catastrophe."

Low-income countries responded to the report by calling for more financing for climate mitigation, including high-income nations such as the US and UK delivering on their 2009 promise of $100 billion a year by 2020, which is only at $80 billion according to the latest estimate. "The IPCC report findings reinforces the urgency to step up and take action – with more ambitious [climate plans], long-term decarbonisation plans and more climate finance – well before the doors open at COP26," said Sonam Wangdi at the Least Developed Countries Group in a statement.

One message of the report that may have an instant impact is that "it is now an established fact" that climate change is linked to extreme weather events like the heatwaves and floods that have hit countries from Canada to China this year. "I think the increasing ability to link specific events with confidence to climate change, that boosts the narrative [for action on emissions]," says Betts.

This stronger link could spur greater investment in adaptation to a warming world. "Now that people are joining the dots that climate change is here and it's having nasty impacts, that has the potential to focus the minds of individuals," says Bob Ward at the London School of Economics. "It's no longer a theoretical, remote issue, but it's here and now." Societies will have to increase their resilience as many climate change effects are already locked in for decades, he says.

Liz Stephens at the University of Reading, UK, who works with humanitarian organisations including the Red Cross movement, says such groups will be calling for more investment in "anticipatory action" at COP26. This involves early warning systems for flooding and heatwaves caused by extreme weather, as well as making sure that those systems are used by communities. "The countries most at risk of climate change are really seeing the impacts of extreme events now. They will rightly be looking for support from countries that have caused climate change to help them adapt," she says.

The report could also positively influence political debate about the cost of measures to make economies hit net zero. This will be high on the agenda in the UK in coming months, as the government outlines new elements of its net-zero strategy, including what to do about fossil fuel heating in homes, which is expected to cost billions of pounds to change.

In that respect, the report should strengthen the hand of politicians justifying the costs of bold action. "The point about extreme weather is it's damaging," says Ward. "While people go on about the cost of having to make changes [for net zero], they can now see on the other side of the ledger is this damage, which is not just economic but human too. People can now see there is no cost-free option here." ▮

For more on how we will tackle climate change, see page 41

Interview: **Tamsin Edwards**

1.5°C is possible

Don't give up on climate action yet, Tamsin Edwards tells **Adam Vaughan**

THE landmark report released last week by the Intergovernmental Panel on Climate Change (IPCC) has left many people reeling about the current and future state of our planet. But Tamsin Edwards at King's College London, a lead author on the report, says it is understandable that it takes time for the gravity of the situation to sink in. "I think many people aren't that aware that we have already committed ourselves to changes that are irreversible. That is a profound thing to take on board," she says.

Those changes include warmer ocean temperatures, ocean acidification and a decline in oxygen levels in our seas. All are now irreversible on centennial to millennial timescales because of humanity's burning of fossil fuels and other activities. "We are changing the planet. It will continue to change no matter what we do in terms of our emissions, for hundreds to thousands of years. That is beyond our comprehension in many ways," says Edwards.

Her involvement in reviewing the global environmental crisis is intimately connected to her own personal health crisis. Edwards was appointed a lead author on the report in 2018, around the time she was diagnosed with bowel cancer. Three years ago, she delayed chemotherapy to attend a vital meeting in China with some of the 234 other authors of the report (she is now clear of cancer). The covid-19 pandemic pushed those meetings online. They culminated in the final text being approved by 195 governments, a process that adds to the report's gravitas.

Profile

Tamsin Edwards is at King's College London and is a lead author on the latest IPCC report

For Edwards, one key message from the report is the upgrade of human influence on global warming from "clear" in a 2013 IPCC report, to "unequivocal". "The much, much stronger statements on human influence are really striking," she says. "To see that human influence is the main driver of air temperatures, ocean temperatures, hot extremes, Arctic sea ice loss, glacier loss, sea level rise and many other aspects as well, it's an incredibly strong message."

The IPCC's findings may seem gloomy, but Edwards says they also show there is still hope. The report finds that in the very lowest of five scenarios for future carbon dioxide emissions, the world is likely to hit the Paris Agreement's target of 1.5°C of warming in the next 20 years, before cooling later this century to 1.4°C.

"It is important to realise that it is still possible to limit warming to 1.5°C with not much overshoot, with immediate, rapid and large-scale reductions in emissions. Obviously, optimism and pessimism isn't the remit of our report. All we can do is lay out the evidence," says Edwards. ▮

Cybersecurity

VPN flaw could put users at risk

An attack on virtual private networks could see people sent to fraudulent websites

Chris Stokel-Walker

VIRTUAL private networks (VPNs), which have seen a rise in use as more people work from home, are vulnerable to an attack that removes user anonymity, researchers have found.

VPNs work by rerouting your internet traffic through a virtual tunnel that encrypts all data that passes through it and disguises your IP (or internet protocol) address, which is used to identify from where you access the internet. They are often used to access internal networks remotely, such as connecting to workplace servers from home.

The technology has long been considered secure against external attacks, but now William Tolley at Arizona State University and his colleagues say they have found a flaw with VPN infrastructure.

The vulnerability works by monitoring one thing that VPNs cannot hide: the existence and size of the packets of data flowing through them.

"This is more fundamental than a cute trick," says Tolley, who claims his attack works against all VPNs. "It's a fundamental networking vulnerability."

Each user of a VPN is secretly assigned one of around 65,000 possible ports, the entry and exit points to the tunnel through which their data is processed. The first phase of the attack involves sending data packets of different sizes to lots of ports in an attempt to trick the VPN. If a packet is sent to a user's correct port, the VPN will forward it on. Otherwise, the packet will be discarded.

Virtual private networks are designed to keep you secure online

SHUTTERSTOCK/KSENIA ZVEZDINA

By monitoring traffic through the VPN tunnel and the size of the data packets that make it through, it is possible to identify a user's port. Hackers can then send packets where they have modified the source address to appear as though it is from one of the legitimate ends of the connection, which can send users to a fake website or inject malicious data into any websites they visit.

The researchers presented their work at the Usenix Security Symposium last week. They say they have reported the attack method to a number of VPN providers, but it is likely that not all VPNs in use today will be patched to prevent the vulnerability. "Our advice is to avoid VPNs if you're trying to keep your information private from government entities," says Tolley, but he says they could be OK in other situations. "It depends on the use case."

The use of VPNs has become more popular as people work from home and require secure access to work files stored on business servers. They are also used by some people to subvert geographical region locks on services such as Netflix, and by those living in countries ruled by repressive regimes to try to avoid surveillance.

"I really like what the authors have done," says Gareth Tyson at Queen Mary University of London. "They've found a bunch of flaws and put them together to discover a comprehensive attack." Yet Tyson points out that the skill level required to carry out a successful attack is more than the average hacker is likely to have. "These attacks can't be performed by some kid in the basement. It's something that does require some dedicated effort, and in some cases a pretty powerful adversary."

Tyson points out that attackers would require a physical presence in the correct parts of an IT network in order to carry out the level of intrusive packet monitoring required. "In an authoritarian regime where the state controls all the infrastructure, that would be much easier," he says. ▮

Astronomy

Huge stream of gas may be unknown arm of our galaxy

WE MAY have found part of a never-before-seen arm of the Milky Way galaxy. This huge stream of gas – named Cattail because of its long, thin shape – is the largest and most distant gas filament ever spotted in our galaxy.

Keping Qiu at Nanjing University in China and his colleagues found one end of Cattail using the Five-hundred-meter Aperture Spherical radio Telescope (FAST) in China. They then searched data from the HI4PI survey, an all-sky search for hydrogen gas, to confirm it and detect the rest of the enormous structure.

The researchers found that this filament of gas is more than 16,000 light years long and about 675 light years wide, with a mass around 65,000 times that of the sun (arxiv.org/abs/2108.01905). It is nearly 72,000 light years away from the centre of the galaxy, placing it right on the edge of the Milky Way.

While Cattail's mass may seem extreme, its density is so low that it is probably mostly made of gas alone. "The gas density of this structure is way too low to form a star," says Qiu.

If it is just a filament of gas, it is unclear how it could have been formed – astronomers don't know of any process that would make such a filament so far from a galaxy's centre.

It is also possible that Cattail could be a new outer arm of the spiral galaxy, although it doesn't have quite the same shape as the four known arms.

"If Cattail is part of a new spiral arm, it means that we might know less than we thought"

"If Cattail is part of a new spiral arm, it means that we might know less than what we thought, especially if it could not be traced back or connected to a known major arm," says Qiu. "If the structure is part of a new arm, it's puzzling that it doesn't fully follow the warped pattern of the galactic disc."

We will need more observations of Cattail's entire length to determine whether it is indeed an arm of the Milky Way. ▮

Leah Crane

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Coronavirus

The ventilation problem

Maximising airflow in public spaces is crucial to cut covid-19 transmission, but questions remain about what technology to use and how effective it needs to be, says **Graham Lawton**

AS THE nights begin to draw in and schoolchildren across the northern hemisphere start trooping back into the classroom, there are three words that ought to be inscribed on every blackboard: ventilation, ventilation, ventilation.

"Ventilation is a critically important control measure for covid-19," says Cath Noakes, an environmental engineer at the University of Leeds, UK, and a member of the UK government's Scientific Advisory Group for Emergencies (SAGE).

Schools are a particular weak link in controlling the spread of the virus, being crowded with largely unvaccinated children who find physical distancing a challenge. But the mantra should also be repeated in all places where people congregate in large numbers: offices, pubs, restaurants, universities, gyms, healthcare facilities, entertainment venues, public toilets, places of worship and public transport.

This focus on ventilation has come about because of our evolving understanding of how the SARS-CoV-2 coronavirus is transmitted.

In March 2020, the World Health Organization (WHO) issued advice on Twitter stating "FACT: #COVID19 is NOT airborne. The #coronavirus is mainly transmitted through droplets generated when an infected person coughs, sneezes or speaks."

Since then, mounting evidence to the contrary has convinced the WHO to change its position. It now accepts that airborne transmission of the virus is critically important.

In March 2021, the WHO issued new guidance on ventilation. "The risk of getting COVID-19 is higher in crowded and inadequately ventilated spaces… These environments are where the virus appears to spread by respiratory droplets or aerosols more efficiently, so taking precautions is even more important," it said.

"We know now that the virus can be transported across a room in very small particles, and it can build up within the room if ventilation is poor," says Noakes. "And we know that poor ventilation is associated with superspreading."

But ventilation is often an intangible issue. "Ventilation is one of the hardest mitigations to apply well," says Noakes. "Air is very complex. There's not a single, simple rule [like] 'wash your hands for 20 seconds'. Even a rule like 'open a window' has nuance to it: one day you might get good ventilation, the next day you might get different ventilation."

Defining what constitutes good ventilation is up in the air, too. The basic parameter is how many times the air in a space is completely replaced per hour, but how that translates to protection from virus-laden aerosols is hazy. "We don't really know what are the right ventilation rates we need in buildings to manage infection, and every building is different," says Noakes. "I do think we need some new research."

Unknown air quality

That makes it difficult for individuals to gauge whether a space is adequately aired. "For people to act responsibly, they need support from the [UK] government," says Stephen

PAUL BERSEBACH/MEDIANEWS GROUP/ORANGE COUNTY REGISTER VIA GETTY IMAGES

First day back at Tustin Ranch Elementary School in California on 11 August

9%

Maximum fall in productivity due to poor air quality in the office

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Reicher at the University of St Andrews, UK. “It’s all very well the government advising everyone to ‘ventilate’, but how can you know if public spaces aren’t well-ventilated if we don’t have clear standards, if those standards are not publicised and if the spaces are not monitored?”

But there are things that can be done. From an individual point of view, the most effective action is to invest in a carbon dioxide monitor, which estimates the concentration of exhaled air in a room (see “How well ventilated is my local area?”, below). “The amount of CO_2 tells you how much of that air in that room was breathed out by other people,” says Noakes. “So it’s a proxy for the ventilation rate.”

Building owners and managers also have a key role to play. “How buildings are managed makes a big difference,” says Peter Guthrie, vice president of the Royal Academy of Engineering in London.

Unfortunately, says Guthrie, ventilation is often near the bottom of their to-do list. “Ventilation is particularly likely to be neglected. It can be difficult to get right, people tend not to notice it and unlike other important issues, such as hand hygiene and cleanliness, which are visible signs you are taking your responsibility seriously, ventilation is an invisible feature,” he says.

“Building management is sometimes seen as a bit of a chore, and a cost that’s got to be met,” says Hywel Davies at London’s Chartered Institution of Building Service Engineers. “Nobody is very enthusiastic about it and building managers are often given incentives to focus on the more eye-catching activities, such as one-way systems, hand sanitiser and frequent cleaning.”

But this “hygiene theatre” does little to address the risk of spreading covid-19, says Gabriel Scally, president of the Royal Society of Medicine’s Epidemiology & Public Health Section in London.

Even where buildings have adequate ventilation systems, they are often poorly maintained and managed. In the UK, top-class ventilation is found in a small percentage of buildings, says Guthrie. “Most people spend most of their time in buildings that have far less sophisticated ventilation systems,” he says.

Companies often regard good indoor air quality as an expensive luxury, but that is a false economy, says Shaun Fitzgerald at the University of Cambridge. He points to research from Denmark showing that poor office air quality cuts productivity by up to 9 per cent, or about half a day a week per employee. “That’s what I would call a seriously good investment,” says Fitzgerald. “Businesses should think about how much their poor air quality is already costing them.”

Air conditioning can make the problem worse. “Sometimes air conditioning is part of the mechanical ventilation system and that is probably OK because it’s cooling the air and supplying fresh air at the same time,” says Noakes. “But many buildings have recirculating units. Those are the worrying ones because they mask the fact that the ventilation’s poor. They make you feel comfortable, but all they’re doing is recirculating the same air over and over and over again.”

Buildings without mechanical ventilation systems that rely on natural sources of fresh air such as windows are another headache.

> **“Everyone perceives the Tube in London as badly ventilated, but there’s quite a high flow rate”**

“Do all the windows which are supposed to open actually work?” says Fitzgerald. “It is a fact of life that many windows which are at a low level and easily accessed by occupants are better maintained than higher windows. Top windows get painted shut and then they’re out of action. Losing a few windows really is a problem in winter. By cracking open all the high-level windows a small amount, you can get rather good levels of ventilation but without cold draughts: the incoming cold air will mix with the air in the space and be warmed before it hits the nearest occupant.”

Bringing in fresh air from low-level windows can make a space intolerably cold, so people shut them, says Fitzgerald. “Last winter, some buildings in the UK were very cold, particularly schools,” says Noakes. “This is what we need to avoid,” says Fitzgerald.

Public transport in the UK, and elsewhere, can also be problematic. “Trains and buses are designed for comfort not for ventilation,” says Guthrie.

However, while research is limited, some public transport systems appear well-ventilated, says Noakes. In the UK, mainline trains often have good mechanical ventilation and they usually open their doors frequently, she says. Also, many station concourses ›

How well ventilated is my local area?

The easiest way to check whether a space is well ventilated is to use a carbon dioxide monitor. The amount of CO_2 tells you how much of the air present was breathed out by other people, providing there is no other source like a gas stove. Outdoor air has a CO_2 concentration of about 410 parts per million (ppm). While there is no specific data on how ventilated a space must be to prevent coronavirus transmission, below 800 ppm is considered by scientists to be well ventilated, above 800 ppm is cause for concern and above 1500 ppm screams “get out”. *New Scientist* tested the air in various environments around London.

Space	Details	Highest reading (ppm)
Outdoors		413
Bus	Upper deck, half full, windows open	741
	Lower deck, full, doors opening at stops	724
London Tube	Platform, between trains	783
	Platform, after train departs	419
	Empty carriage with open windows	542
	Half-full carriage with open windows	976
	Full carriage, standing room only	1076
Overground train	When doors are open / closed	413 / 720
Private car	Two people, windows closed	1740
	Two people, recirculating air con on	1589
	Two people, windows open	413
	Two people, non-recirculating ventilation on	413
Supermarket	Large, empty	413
	Small, busy	1100
Restaurant	Busy, by open door	739
Office	*New Scientist* office, less than half full	477
Pub	Main bar, full, doors and windows open	420

are large enough to dilute any airborne virus to low levels.

Aeroplanes and many underground trains are also surprisingly airy. "Everybody perceives the Tube [in London] as really badly ventilated," says Noakes. "The air quality is poor, but there's actually quite a high ventilation flow rate in an underground train. Planes also have quite good ventilation systems on the whole: although they recirculate the air, they recirculate it through good filters."

New Scientist used a CO_2 monitor to assess the ventilation rate on the London Underground and found it varied enormously depending on the position in the carriage and, unsurprisingly, how busy it was. On a train with standing-room only, the CO_2 levels quickly rose, but on a quiet train next to an open window between carriages, it dropped back to an acceptable level of ventilation.

Prompting a revolution

Filters might also be the answer for some buildings. Various high-tech solutions such as HEPA (high-efficiency particulate absorbing) filters and UV disinfectors are available. But they shouldn't be seen as magic bullets, says Noakes. "Some are potentially very beneficial, but just because you've got one doesn't suddenly mean everyone is safe. Air cleaners will work well in some spaces, but not in others. It's all about the right tech in the right environment. There's a real gap here in understanding how we actually deploy these technologies."

There is also a risk of building owners and managers squandering money on high-tech solutions when maintenance of existing systems would pay higher dividends, says Fitzgerald.

We may have more clarity on how useful filters are soon. Last week, it was announced that 30 primary schools in Bradford, UK, would take part in research testing whether HEPA filters or UV can help cut covid-19 transmission.

Overall, says Noakes, there are no easy answers, and ventilation alone won't keep us safe. "We have to remember that ventilation only mitigates airborne transmission beyond about one-and-a-half metres from a person," she says. "We need to therefore make sure there are also other measures in place at the same time: masks, distancing, surface cleaning and hand hygiene."

But once the northern hemisphere gets through the next winter, there may be a revolution in the air. The pandemic has focused minds on the wider problem of unsafe indoor spaces, and in May an international team of researchers published a call in the journal *Science* for a fundamental rethink.

According to lead author Lidia Morawska at the Queensland University of Technology in Australia, today's indoor air quality standards fail to protect us from airborne pathogens such as viruses and bacteria, and must be upgraded to deliver better ventilation, filtration, disinfection and public displays of the state of indoor air quality.

"We wouldn't tolerate our children drinking dirty water, but we seem to tolerate dirty air"

Commuters board a Jubilee line Underground train in London on 19 July

HOLLIE ADAMS/BLOOMBERG VIA GETTY IMAGES

Even the recent guidelines from the WHO don't go far enough, says Morawska. The scale of the change required is equivalent to the sanitary revolution of the 1800s, she says, when cities such as London realised that contaminated water was a deadly public health problem and began work to build clean water supplies and sewage systems.

In some places, change has begun. In New York City, for example, the ventilation status of every classroom in the public school system is published on a website, and classrooms must have at least two functioning methods of ventilation. Belgium has begun the process of mandating that all public buildings display their CO_2 levels.

Scientists say that action cannot come soon enough in the UK, especially given the government's decision not to mass vaccinate the under 16s.

"This is an airborne disease," says Scally. "If it was coming through our water supply we'd take action, and we should be taking action with our air supplies." Just as restaurants have to be regularly inspected for their food hygiene, public spaces should be regularly inspected for ventilation, he says.

Reicher agrees. "We wouldn't tolerate our children having to drink water which infects them, but we seem to tolerate dirty air. There's got to be a fundamental change in attitude." ▮

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Evolution

Stripped-back cell still evolves

A bacterial cell engineered to contain just 493 genes can adapt to its surroundings

Michael Marshall

AN ARTIFICIAL "minimal cell" that has had all but the most essential genes stripped out can evolve just as fast as a normal cell. The finding shows that organisms can rapidly adapt, even with an unnatural genome that provides little flexibility.

"It appears there's something about life that's really robust," says Jay T. Lennon at Indiana University in Bloomington. "We can strip it down to just the bare essentials," he says, but that doesn't stop evolution going to work.

Lennon and his team studied a bacterium called *Mycoplasma mycoides*, a parasite that lives in the guts of animals like cows. Because it gets most of its nutrients from its host, *M. mycoides* has naturally lost a lot of genes.

In 2016, researchers led by Craig Venter at the J. Craig Venter Institute in California reported that they had stripped the bacterium's 901-gene genome back even further, to just 493 genes. The resulting synthetic organism, *M. mycoides* JCVI-syn3B, has a "minimal genome", the smallest of any known free-living organism.

M. mycoides JCVI-syn3B can grow and divide normally, but Lennon wondered what would happen to it in the long term. Species need to change to survive, but it seemed likely that the minimal cell would have trouble evolving.

"Every single gene in its genome is essential," says Lennon. "The cell has zero degrees of freedom." As a result, any mutations that arise would be expected to be harmful.

Lennon's team began by establishing that the minimal cell could still mutate. It does so to such a degree that, even given a small population size of just 10 million, every single genetic "letter" would be expected to mutate more than 250 times over 2000 generations.

The team then grew *M. mycoides* JCVI-syn3B in the lab, allowing them to evolve freely for 300 days.

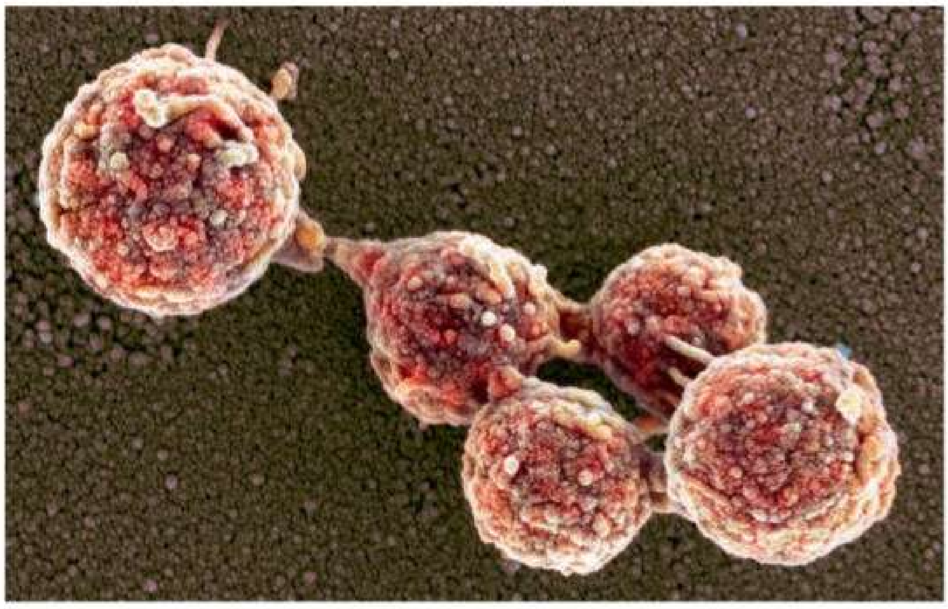
Next, the team set up some head-to-head contests. In some experiments, the minimal cells that had evolved for 300 days were pitted against the original, non-minimal *M. mycoides*. In others, the non-minimal cells went up against minimal cells that hadn't evolved for 300 days.

In all contests, the team put equal quantities of the strains being assessed in a container and observed which one became more common, a sign of which was better suited to its environment.

The unevolved minimal bacterium was "really sick", says Lennon, and was easily outcompeted by the non-minimal version. But the version that had evolved for 300 days did much better, recovering 80 per cent of the lost fitness (bioRxiv, doi.org/grck).

Crucially, the team identified the genes that changed most during these evolution contests, says Zan Luthey-Schulten at the University of Illinois at Urbana-Champaign, who wasn't involved in the study. Some have unknown functions. "You have to go and ask yourself, 'What does that thing do?'" she says.

Mycoplasma mycoides JCVI-syn3B has had many of its genes removed



THOMAS DEERINCK, NCMIR/SCIENCE PHOTO LIBRARY

Solar system

Mercury has almost no boulders and we're not sure why

THERE are barely any boulders on Mercury. Rocks that are at least 5 metres across are far less abundant on the planet's surface than expected, and figuring out why could help us understand conditions on the closest planet to the sun.

Since Mercury is difficult to reach with a spacecraft, we have few high-resolution images of its surface. Most of them come from NASA's Messenger mission, which orbited the planet from 2011 to 2015. Mikhail Kreslavsky at the University of California, Santa Cruz, and his colleagues examined about 3000 of the clearest of these images, searching for boulders.

The researchers spotted boulders in only 14 images. To determine whether this number was unusual, they compared the Messenger images with pictures of the moon taken by NASA's Lunar Reconnaissance Orbiter. After using an algorithm to lower the quality of the moon pictures to match the ones from Messenger so the two data sets were comparable, they found that boulders are about 30 times less abundant on Mercury than on the moon (arxiv.org/abs/2108.01528).

"In many senses, Mercury is like the moon, but in this sense it is different," says Kreslavsky.

There are some potential causes for this dearth of large rocks. Mercury may have a thicker layer of dust covering its bedrock. Boulders are formed when impacts break off bits of bedrock, so thicker dust would act as a protective layer that makes this less likely.

"Images show that boulders are about 30 times less abundant on Mercury than on the moon"

Also, Mercury is much closer to the sun than the moon is, so it experiences extreme temperature variations and gets far hotter. This could degrade any boulders that do form, as could the larger amount of micrometeorites that hit Mercury.

The true explanation is probably a combination of these factors, says Kreslavsky, but the BepiColombo spacecraft – which is on its way to Mercury and is due to arrive in 2025 – should help us work it out.

Leah Crane

Herd immunity to covid-19 may not be attainable in the UK

A high vaccination rate will save many lives, but it probably won't be enough to stop covid-19 becoming a seasonal disease, finds **Helen Thomson**

THROUGHOUT the covid-19 pandemic, there has been constant reference to the tantalising phenomenon that signals the end: herd immunity. This is when enough people are immune to a virus that it can't spread, therefore protecting the whole community, even those who aren't immune.

More than 18 months into the pandemic, and with 59 per cent of the UK having received two doses of a covid-19 vaccine, how far is the country from the herd immunity threshold, and how will we know when it has got there?

Let's get the bad news out of the way: it is unlikely to be soon and may not be attainable at all. The good news is that we may not need herd immunity to live alongside the virus.

To appreciate why, first we need to understand herd immunity at its simplest: it is the point at which each person with covid-19 infects less than one other susceptible individual. This causes infections to decrease, with only sporadic cases that don't spread widely.

In theory, you can reach this goal through vaccination or past infection, as both provide some immunity from future infection. In reality, we have only reached herd immunity for other viruses, such as smallpox, through vaccination.

A key data point for herd immunity is the basic reproduction number – known as R or R0 – which is the average number of people one person with an infectious disease will infect.

At the pandemic's start, the R0 for the coronavirus was 2.5. It has since risen as the virus evolved to become more transmissible. Latest estimates put the delta variant's R0 between 5 and 9.5, says Willem van Schaik at the University of Birmingham in the UK. "This would put the herd immunity threshold at between 80 and 90 per cent of the population [being vaccinated]."

That may be possible to reach, but no vaccine is 100 per cent effective. Although current covid-19 vaccines are extremely effective at preventing severe disease, they don't completely block infections in everyone, which means some vaccinated people might still be able to pass on the virus. The latest data suggests that vaccines are up to 79 per cent effective against symptomatic infection from delta.

The road to herd immunity gets more complex when you consider other influencing factors, including how much social contact communities have, the age at which someone first gets infected, how people's immune systems differ, how influential pre-existing immunity is and the potential impact of genetics.

The only way to guarantee herd immunity is to have extremely effective vaccines that provide near-sterilising immunity – in which pathogens are completely prevented from replicating – and have high uptake of these, says van Schaik. Considering these factors, it would take the impossible feat of vaccinating more than 100 per cent of the UK population to reach herd immunity, says Paul Hunter at the University of East Anglia in the UK.

79%

Efficacy of vaccines against symptomatic delta infection

You might think population immunity would build slowly over time as people gain immunity after infection. Unfortunately, immunity to covid-19 appears to be relatively short-lived, meaning reinfection is possible and booster shots may be needed. In addition, variants can evolve to evade existing immunity and push the goalposts back.

RICHARD BAKER/IN PICTURES VIA GETTY IMAGES

National Health Service staff out in London to encourage vaccinations

Finally, the varying speed and distribution of the global vaccine roll-out means that even if one country with high vaccination rates, such as Israel, gets past the herd immunity threshold, contact with people from other nations with low vaccination levels could spark new outbreaks. The UK has seen this happen with measles.

Ultimately, it all adds up to "no chance of ever reaching herd immunity for covid", says Hunter. He adds that at a UK all-party parliamentary committee held on 10 August, attending scientists were unanimous in their opinion that the UK wasn't going to reach herd immunity. Instead, most researchers seem to agree that the UK will reach what is known as an "endemic equilibrium", whereby covid-19 becomes seasonal.

The only way to avoid that situation is to get more than 95 per cent vaccine coverage in people over 12 and have a booster every year, or to develop a vaccine that creates sterilising immunity, says Thomas House at the University of Manchester in the UK. "Or we could accept that there will be further waves, much like influenza," he says. "Before we had the vaccine, it wasn't appropriate to compare covid to flu because covid was so much worse. We shouldn't be sanguine about covid, people underestimate the effects, but post-vaccine we can compare the illness to flu."

Hunter's view aligns: "When we reach the endemic equilibrium, we will see infections vary from summer to winter and from one year to the next." But we can expect to see fewer and fewer of those infections causing severe disease, he says.

This all points in one direction: nobody should be banking on herd immunity. "Everybody should have the vaccine," says van Schaik. "Nobody can rely on 'the herd' for absolute protection against an illness that is potentially deadly and can have long-term health consequences." ■

Robotics

Snake-like robot could explore Saturn's icy moon

Matthew Sparkes

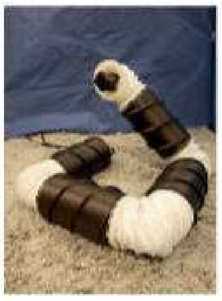
A SNAKE-like robot made of giant screws and flexible joints that can travel across hard or loose surfaces and worm into tiny spaces such as tubes and tunnels may be key to exploring the interior of Saturn's frozen moon Enceladus.

The ARCSnake is formed of modular segments and propels itself with Archimedes screws. These helical devices push material backwards to move the robot forwards. Half the screws rotate clockwise and half anticlockwise to prevent the robot from simply rolling sideways, although making them both rotate in the same direction does allow it to quickly roll sideways along flat ground.

The motors, control systems and sensors are housed inside the hollow screws. The 6.1-kilogram robot is operated by a human controller manipulating a miniature scale model of it remotely.

Due to the robot's numerous joints, this is currently the most intuitive way to steer it, but future versions designed for exploration could be controlled differently or even entirely automated (arxiv.org/abs/2107.14427).

Parts of the machine were inspired by previous work on a device designed for colonoscopies, but it is now being investigated by NASA's Jet Propulsion Laboratory for a possible mission to Enceladus. Florian Richter at the University of California, San Diego, and his colleagues hope to work on an improved version of the device for NASA in the coming months. ▮


ARCLAB

The ARCSnake robot is made from Archimedes screws linked by flexible joints

Briefing

What is a metaverse?

An old idea is gaining new traction through online gaming and big tech's bet on virtual reality, says **Matthew Sparkes**

EPIC GAMES

Ariana Grande's avatar giving a concert inside *Fortnite*

MILLIONS of Ariana Grande fans attended her concerts last week, held not in a traditional venue, but within the video game *Fortnite*. These events, complete with music and 3D graphics, are an example of Silicon Valley's new favourite buzzword: metaverse.

What is a metaverse?

It's a shared online space that incorporates 3D graphics, either on a screen or in virtual reality. Science fiction author Neal Stephenson coined the term in his 1992 novel *Snow Crash*, which features a future virtual reality version of the internet called the Street. More recently, a metaverse called OASIS featured in the novel and film *Ready Player One*.

Are there real-world metaverses?

Perhaps the first attempt to create a real metaverse was *Second Life*, which launched in 2003 and grew to around a million regular users at its peak. It had its own currency and users could build property, organise events and design their own avatar, but there was nothing specific you were supposed to achieve. Duran Duran staged concerts within *Second Life* in 2006.

Other game developers also have their eyes on becoming a metaverse. Take *Roblox*, which allows players to create and share their own games. "Just as the mail, the telegraph, the telephone, text and video are utilities for collaborative work, we believe *Roblox* and the metaverse will join these as essential tools for business communication," co-founder David Baszucki told *The New York Times*.

1992

The year the term "metaverse" was coined by author Neal Stephenson

I've also seen Mark Zuckerberg talking about a metaverse.

Last month, Facebook founder Mark Zuckerberg announced that the company will become, or at least spawn, a metaverse called Horizon. On top of the current web and app versions of Facebook, it will offer either augmented reality or virtual reality universes.

Microsoft, too, is talking about becoming a leader in the field of "metaverse apps" and also has its own augmented reality hardware, HoloLens.

Why is everyone so keen all of a sudden?

The hardware and software are now sufficiently advanced. Spearheaded by gaming, metaverses using virtual or augmented reality on affordable devices could become far more popular and start offering truly practical or entertaining features. And of course, there is a lot of money to be made. *Fortnite* made $9 billion in revenue in 2018 and 2019 combined, with people paying to customise their avatars.

What other tech is needed?

The decentralised technology behind cryptocurrencies may play a role. One metaverse called Decentraland has a currency that can be used to buy land or non-fungible tokens (NFTs), a form of unique digital items. Auction house Sotheby's, which is pushing hard into the NFT world, owns a piece of Decentraland, where it has built a replica of its London galleries. This is the kind of thing organisations were getting up to in *Second Life* over a decade ago.

Meanwhile, the Open Metaverse Interoperability Group is pushing for different metaverses to share technology so that avatars can move easily from one to another. ▮

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8 days | 30 October and 6 November 2021

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Join an unforgettable tour of Iceland's majestic landscapes, scheduled to maximise days filled with volcanic and geological adventure, and evening opportunities to see the Aurora Borealis.

Spend time with leading geologist Oliver Shorttle, discovering the might of the planet as you marvel at the sights, sounds and smells of erupting geysers, hot springs, and bubbling mud. Plus, stunning glaciers, waterfalls and visible tectonic plates pulling apart. Staying at four different hotels to reduce travelling and see more of Iceland.

Highlights

- Join talks and walking seminars from Oliver Shorttle.
- Tour Þingvellir National Park, the site of Iceland's first parliament, founded in 930, and a geological wonder where the American and Eurasian tectonic plates are pulling apart.
- Visit Iceland's Geysir geothermal area, where you'll see the Strokkur geyser shoot water 30 metres into the air. Be spellbound by the immense beauty and sheer power of the Gullfoss Waterfall.
- Super jeep drivers will take you to the elegant Seljalandsfoss waterfall, which is unique in its kind, as you can walk behind the plummeting falling stream without getting (too) wet, for a unique viewing angle.
- Cross the deep and roaring rivers that guard the wooded surroundings of Thórsmörk, where you will have time to hike around the area and admire some of the many viewpoints it offers.
- A trip to the eerily beautiful Skógafoss waterfall, one of the biggest waterfalls in Iceland. 25 metres wide with a 60-metre drop. You will feel the immense power of the waterfall close-up, as you climb a long windy set of stairs to a truly stunning viewpoint.
- Visit the famous Jokulsarlon Glacier Lagoon, a stunning sea of floating icebergs. Weather permitting, there will be an opportunity to step outside and witness the natural wonders of the Northern Lights.
- Walk on Europe's biggest ice cap – Vatnajokull, which has around 30 glaciers flowing out from it.
- Enjoy lunch in the black sand seaside town of Vik. The sea on one side and high cliffs on the other, dramatically positions this quaint little village as Iceland's most southerly mainland settlement.
- Visit the Lava Centre, an interactive, high-tech educational exhibition depicting volcanic activity, earthquakes, and the creation of Iceland over millions of years.
- Relax in the warm thermal waters of natural hot springs in the village of Fludir.

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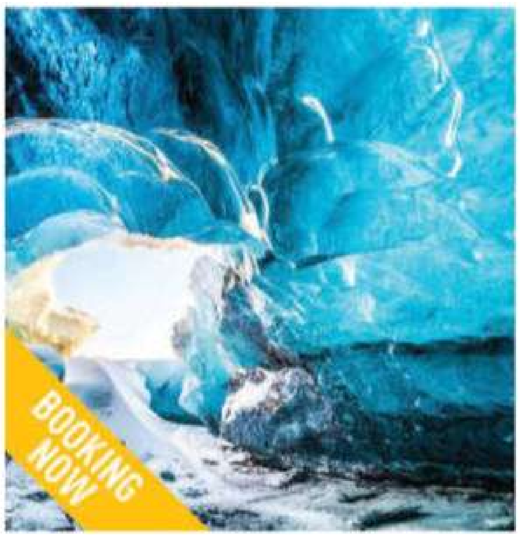

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Technology

A handheld railgun as powerful as an air rifle is driven by electromagnets

David Hambling

AN ELECTROMAGNETIC rifle, which propels a steel projectile using electromagnetic coils, is now being offered for pre-order in the US by Arcflash Labs, a Los Angeles company specialising in industrial pulsed power devices.

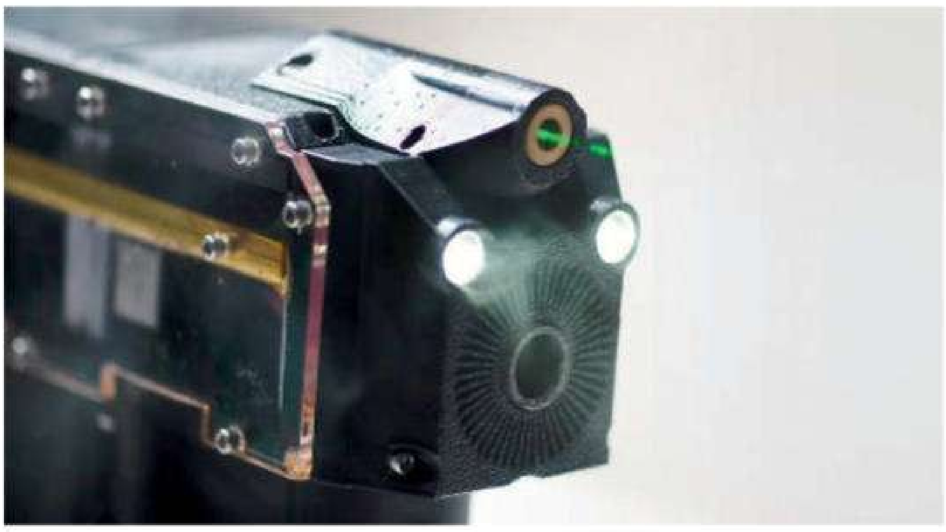
The device, known as the GR-1 ("Gauss rifle") ANVIL, is like a smaller version of the US Navy's giant experimental railguns. It is a coilgun, with eight sets of electromagnetic coils that attract and accelerate the projectile down the barrel.

Its makers say it has a muzzle energy – the energy of a bullet as it leaves the barrel – of around 85 joules, comparable to high-end air rifles used for hunting. At 9 kilograms, it is heavier than traditional weapons, and at $3375, it is also more expensive.

Arcflash co-founder David Wirth says two developments have made the GR-1 possible: low-cost commercial semiconductor switches and the company's patented inverter. This transfers power from a battery to capacitors that can discharge rapidly enough to fire a bullet. The rate of fire is limited by how fast the capacitors can be charged. With Arcflash's inverter, the weapon can fire 100 rounds a minute rather than waiting minutes for each shot.

The muzzle energy is still comparatively low, due to capacitor limitations. Wirth says that capacitor storage is growing steadily and the weapons will eventually rival traditional firearms. Arcflash received initial development funding from the US Army, but Wirth cannot discuss the firm's current military work.

Electromagnet coils in the GR-1 ANVIL propel projectiles



ARCFLASH LABS

Wirth sees stealth and logistics as key advantages of the GR-1. Ammunition is much simpler, requiring just a projectile without any propellent or cartridge. A standard lithium polymer battery can power 1000 shots and can be recharged in the field using solar power or other sources.

Being able to vary the muzzle velocity may make the technology useful for non-lethal ammunition such as rubber bullets. "The scalable effects of a Gauss rifle would allow law enforcement to fire rubber bullets at a speed proportional to their distance to target, so they're less likely to injure someone if they're close and more likely to reach the intended target if they're far away," says Wirth.

He says researchers and animal control specialists have enquired about using electromagnetic rifles to fire tranquiliser darts more safely and at longer range than currently possible.

Robert Bunker, an analyst at security consultancy firm C/O Futures, says that the lack of a loud report and muzzle flash in night engagements give it significant stealth advantages. "If the kinetic energy levels increased, the Gauss rifle would be ideal for sniper use," says Bunker. "Traditional conical bullets could potentially be replaced by ring-airfoil projectiles, which may offer enhanced body armour penetration and wounding capabilities."

He says such devices have long been expected to replace traditional weapons. "The question, however, is when." ▮

Botany

Insect-killing plant found by Australian road new to science

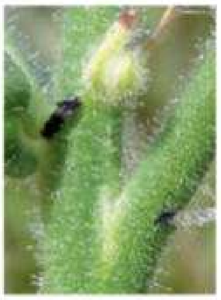
A NEWLY described species of wild tobacco that scientists found growing next to a highway truck stop in Western Australia is covered in sticky glands that trap and kill insects, including gnats and flies.

While a range of carnivorous plants are known across the plant kingdom, this is the first wild tobacco plant discovered to kill insects. Dubbed *Nicotiana insecticida*, it was uncovered by a project looking for *Nicotiana* species across Australia.

The team, which included Mark Chase of London's Royal Botanic Gardens, Kew, collected seeds from the plant at a truck stop on the North West Coastal Highway. They then cultivated them at Kew, where the plants went on to develop the same sticky glandular hairs and to kill insects inside the greenhouses (*Curtis's Botanical Magazine*, doi.org/gq9m).

The insect-ensnaring hairs resemble those on carnivorous sundew plants, but it isn't clear if the plant extracts any food from the insects it kills. "We have no evidence that there is any nutritional benefit to the plant," says Chase, who adds that the team plans to test whether the plant absorbs nutrients.

But even if it doesn't absorb nutrients, killing insects in this way could still be beneficial for *N. insecticida*. "It definitely protects the plants from insects like aphids," says Chase.



MAARTEN CHRISTENHUSZ

Nicotiana insecticida has sticky hairs that trap insects

The plants may also benefit when the dead insects decay. Chase says the species may be like South African *Roridula* plants, which kill insects in the same way. "There is a bug that lives on these plants and is not trapped by the sticky hairs. It eats the trapped insects and defecates on the ground, and the plant benefits from this," says Chase. However, there is no evidence yet that this is what happens with *N. insecticida*. ▮

Penny Sarchet

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SHUTTERSTOCK/ETHAN DANIELS

Animal behaviour

Monkeys navigate using mental maps just like us

BLACK howler monkeys move through their environment using mental maps that they modify and adapt as the landscape changes – a skill previously seen only in humans.

In 2016, Miguel de Guinea at Oxford Brookes University, UK, and his colleagues spent a year in Palenque National Park, Mexico, tracking groups of black howler monkeys (*Alouatta pigra*) to see how they cross the landscape.

While most animals move through an environment semi-randomly or by instinct, humans are different. We tend to follow familiar routes encoded in mental maps. We also have a spatial sense of how locations are arranged in the landscape. This means that if an obstacle blocks a familiar path, we can change course – perhaps switching to another familiar route heading in a different direction – to navigate the obstacle and still reach our desired destination.

As the researchers studied the black howler monkeys, they realised the primates do this too. For that example, the monkeys in the study would always approach favourite fruit trees from the same direction.

What's more, while the monkeys rarely deviated from established routes, they had no problem doing so if, for instance, a tree forming part of a route had fallen down. In such cases, the monkeys quickly worked out how to connect the broken route to another familiar route, so they could navigate the obstacle and still reach their target.

They could also connect routes end to end to travel long distances (*Journal of Experimental Biology*, doi.org/grb2). **Cameron Duke**

Domestication

Gut bacteria helped dogs go omnivore

DOG diets often contain more starch than their carnivorous wolf ancestors would get, and an analysis of fossilised dog faeces helps explain how the animals made the change. Long before their genomes adapted to plant-rich chow, their gut microbiome gained a starch-digesting profile.

Due to their close association with humans, it is thought that dogs' diets shifted to less meat and more carbohydrates as farming began. In Europe, this shift occurred between 8000 and 6000 years ago. However, evidence suggests that dogs' genes couldn't produce much amylase – an enzyme that turns starch, a carbohydrate, into sugars – until thousands of years later.

Now, Simone Rampelli at the University of Bologna in Italy and his colleagues have discovered that gut microbes probably helped dogs digest starch before their genomes caught up.

Rampelli's team sequenced DNA in 13 dog faeces fossils from the site of a Bronze Age agricultural community near Bologna. The fossils date from between 3450 and 3600 years ago. Traces of sheep, wheat and grape DNA in the faeces suggest the dogs were omnivores like modern domestic dogs. But dog DNA in the faeces shows the animals had fewer copies of the amylase gene needed to process this diet than are seen in modern dogs.

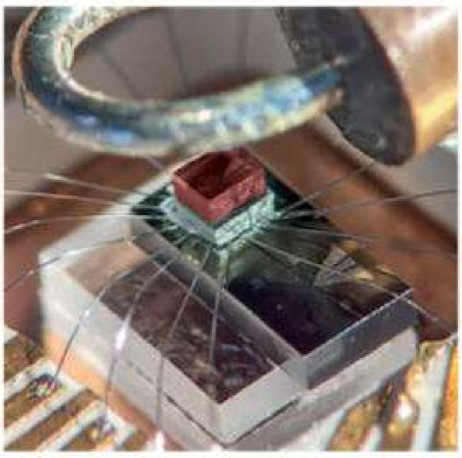
However, the analysis of the faeces also identified 56 microbe species from the ancient dogs' guts, some of which are common in dogs' guts today. Importantly, these metabolise starch by producing their own amylase enzymes (*iScience*, doi.org/grb9).

This suggests that when dogs started eating more starchy food, their gut microbes adapted quickly to allow them to digest it, says Rampelli. **James Urquhart**

Technology

New way to simplify quantum computers

QUANTUM computers are labyrinthine machines the size of a fridge with tangles of control and cooling systems. This complexity is a huge hurdle to scaling up processor power to tackle harder problems. Now, researchers have finally proved that a decades-old theory to simplify silicon quantum processors can work, potentially paving the way for vastly more powerful devices.



JAMES SLACK-SMITH

Most current quantum computers require a control wire for every qubit in its processor to change its spin, or data state, with high-frequency oscillating signals. Each wire is connected to its own microwave source called a cavity and has to reach into the cooled interior of the computer.

Jarryd Pla at the University of New South Wales, Australia, and his colleagues have demonstrated that a single, smaller-wavelength microwave source can cover the entire processor and do away with individual cavities and wires.

Pla says that current quantum computers tend to be an "absolute mess of wiring and all sorts of control systems", but that this technology could simplify them massively.

Cutting-edge quantum computers like Google's Sycamore processor have just dozens of qubits. But practical, useful machines are likely to require thousands or millions of qubits. **Matthew Sparkes**

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Really brief

KATERYNA KON/SCIENCE PHOTO LIBRARY

Source of cancer of oesophagus found

Most tumours of the oesophagus, the tube that carries food from the mouth to the stomach, are caused by escaped stomach cells that go on to become cancerous. The finding suggests it may be possible to screen for the stomach cells and prevent these cancers (*Science*, doi.org/grb3).

Europe sets new record for heat

According to provisional reports, the town of Syracuse in Sicily, Italy, reached a temperature of 48.8°C on 11 August, 0.8°C higher than the previous European record. On the same day, Tunis in Tunisia saw 49°C – a record for the city. Global warming is probably responsible.

Probiotics for coral to beat the heat

Coral may be better able to withstand warming if it is treated with a bacterial probiotic. Treated coral exposed to 30°C water in the lab survived, while untreated coral died. It seems that the bacteria "reprogramme" the coral's genetics to boost survival (*Science Advances*, doi.org/grhz).

Evolution

How the snake got its venomous fangs

DIFFERENT snake species have independently evolved fangs that allow them to inject venom into other animals, either to attack prey or for defence. Now we know how: they turned small wrinkles inside the base of the fang – an ancient feature inherited by most living snakes – into deep channels to carry venom towards the tip.

Alessandro Palci at Flinders University in Australia and his colleagues wanted to explain the origins of venom fangs, which are found in so many species of snake that they must have evolved on several separate occasions.

They used high-resolution microCT scans to look at snake fangs. After examining those from 21 snake species and teeth in two lizard species, they found a common feature. Inside, the dentine tissue near the base of the tooth or fang was folded into a series of vertical wrinkles extending towards the tooth tip – so-called plicidentine structures.

The team found these in both venomous and non-venomous snakes. Species that branch off near the base of the snake evolutionary tree – like non-venomous boas and pythons – have relatively small wrinkles. But in venomous snakes higher up the evolutionary tree, the wrinkles are larger – and one wrinkle has developed into a deep channel to carry venom to the fang tip.

Once any given snake evolved to produce venom, natural selection favoured those with the larger plicidentine wrinkles to help channel the venom to the fang tip (*Proceedings of the Royal Society B*, doi.org/grb4). **Krista Charles**

Climate change

NOAH BERGER/AP/SHUTTERSTOCK

Wildfires may have worsened impact of covid-19 in the US

POLLUTED air caused by smoke from record-breaking wildfires in the US last year has been linked to a rise in covid-19 cases and deaths.

Francesca Dominici at Harvard University and her colleagues say 19,742 recorded covid-19 cases and 748 covid-related deaths can be linked to spikes in tiny particulate matter, PM2.5, from blazes in California, Oregon and Washington.

Links between long-term exposure to dirty air and greater risk of death and severe illness from covid-19 are well-documented. But the new research puts numbers on how short-term exposure, in this case from fires, may have made the pandemic's health impact worse.

The researchers looked at daily data on covid-19 cases and deaths and PM2.5 levels between March and December 2020 in areas with 95 per cent of the population of California, Oregon and Washington.

As a whole, they found each extra 10 micrograms of PM2.5 per cubic metre of air over 28 days was linked to an 11.7 per cent increase in coronavirus cases, and a 52.8 per cent increase in covid-19 deaths (*Science Advances*, doi.org/grhw). The team thinks cases increased due to PM2.5 exposure because it led to more severe illness.
Adam Vaughan

Materials

Printed chain mail is flexible but strong

A FORM of 3D-printed chain mail can alternate between being flexible and rigid, meaning it could be used to make more comfortable medical supports, new forms of flexible armour or even temporary bridges.

Chiara Daraio at the California Institute of Technology and her team used 3D printers to create several versions of chain mail with link shapes such as octahedrons, pyramids and rhomboids. The designs were printed in one go using plastic for some samples and aluminium for others.

The fabrics are flexible and easily drape over objects. But under compression, their links jam together, making the materials up to 25 times stiffer. In one experiment, the team used a plastic fabric weighing just tens of grams to create an arch supporting a 1.5-kilogram weight (*Nature*, doi.org/grb8).

Daraio says that a smart fabric that can adapt its stiffness may lead to innovations in a range of fields. A fine, lightweight mesh of the material could make medical supports for broken bones, but a much larger grid of metal links could even create tents or temporary bridges.
Matthew Sparkes

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Views

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Culture columnist
Gege Li finds TV show *Nine Perfect Strangers* gripping **p34**

Comment

Recarbonise the planet

Regenerating natural systems will draw carbon out of the atmosphere and help tackle climate change. We must do it, says **Jonathon Porritt**

MICHELLE D'URBANO

COMMUNITY by affected community, the true nature of the climate emergency bears down on more and more people every year. Unprecedented wildfires and previously unthinkable floods, in what some glibly refer to as the new normal, prefigures a world of unpredictable, increasingly traumatic abnormality.

As yet, however, neither extreme weather nor stronger warnings in Intergovernmental Panel on Climate Change reports (see page 8) has triggered a proper emergency response from politicians. As we head towards COP26, the big climate conference in Glasgow, UK, in November, incremental decarbonisation best sums up the name of their particular game: gradually reducing greenhouse gas emissions, investing a little bit more every year in low-carbon innovation and new technology.

As with the pandemic, scientists are now exhorting politicians to level with their voters, to tell them how it really is – to explain why halving emissions of greenhouse gases over the next decade is an out-and-out imperative (as the science now tells us) if we are to avoid the horror story of runaway climate change.

In essence, this means preventing those gases getting into the atmosphere in the first place by stopping the burning of all fossil fuels as fast as possible – not just in generating electricity, but in transport, heating buildings and manufacturing. We need to electrify pretty much everything and ensure the extra electricity we will need to power all the heat pumps and battery cars that ensue is 100 per cent renewable.

However, this is only half the story. We have put so many billions of tonnes of carbon dioxide into the air over the past 30 years (much of which will hang around adding to the warming for many decades to come) that we are going to have to remove billions of tonnes of it to avoid that cumulative, long-term warming.

This idea of carbon removal is still highly controversial. It seems completely illogical to be contemplating billions of dollars of investment to remove billions of tonnes of CO_2 – even as we continue to pump huge amounts of this gas into the atmosphere. But we don't have any choice: we now know that a stable climate (and therefore the future of humankind) depends both on accelerated decarbonisation and on getting very good indeed at accelerating carbon removal from the atmosphere.

Happily, there is a big upside in the shape of recarbonising the natural world – letting it draw down excess carbon, for example by promoting tree growth. We need as much as possible of that removed CO_2 to be taken up by regenerating the life support systems on which our economy still entirely depends – including soils, forests, wetlands, peat bogs, mangroves, seagrasses and so on.

The past 70 years of industrial development and intensive agriculture have badly degraded natural systems. There is now a belated, but welcome, recognition that we can't go on producing the food we need by continuing to wage war on nature, and a growing interest in recarbonisation through regenerative agriculture, agroforestry, organic farming and even rewilding.

In essence, recarbonisation opens up an extraordinary prospect of rebuilding soil fertility, restoring forests and woodlands, transforming the marine environment and protecting precious habitats and biodiversity. This all has to happen anyway: it just happens to be an equally powerful way of addressing the climate emergency.

It has taken politicians the best part of 30 years (since the Earth Summit in Rio de Janeiro in 1992) to get going on decarbonisation. They now need to get up to speed on this approach in just a few years, and COP26 has to be the place to make that happen. ▮

Jonathon Porritt is an environmentalist and founder of Forum for the Future

Field notes from space-time

Our love of looking up

The night sky has wowed people since the dawn of time, but it is becoming increasingly difficult to get a good view, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

THANKS to my book release, I have been giving a lot of talks about cosmology, which means I get the opportunity to introduce people to the cosmological timeline and what we know about it.

On an early slide in these talks, I introduce an important before and after: there's the universe before light starts travelling freely through space-time and then there's after. This shift happens at about 380,000 years after the big bang (or whatever came before), when, for the first time, the universe is transparent to light. Before this, the universe is full of what I jokingly call a plasma particle stew that is so dense it is opaque to light; light can't travel far without hitting something.

Today, we can see the light from the moment of transition from opaque to transparent – this is what we call the cosmic microwave background radiation (CMB). The word "radiation" can be anxiety-inducing for people, so I usually tell people not to worry as the CMB has been around for about 13 billion years and humans evolved in a universe where it is everywhere. Even though we couldn't see it and weren't aware of it until about 60 years ago, the CMB has always been with us.

This dynamic more broadly exemplifies a fact about our species: we are a small piece of the universe that has evolved alongside the unfolding of the great cosmic timeline. Part of our specific experience with this is growing up – as a species and as individuals – under a night sky that was relatively predictable, but also occasionally changed.

For example, some celestial objects were so easy to see with the naked eye and so persistent in their patterns that communities around the world gave names to the shapes they saw in them. These constellations stay with us today. Even those of us who don't take astrology seriously typically know which constellation we were born under. And many of us look for familiar constellations like the Big Dipper, also known as the Plough, when we go stargazing.

Occasionally there are dramatic changes. In the year AD 1006, a massive star blew up into a supernova. It remains the brightest stellar event on record, and observations were noted by communities across North America, Africa, the Middle East, Asia and Europe. In other words, humans have long been attuned to the night sky, even before instruments like telescopes were available or in widespread use.

> **"The night sky may forever look dramatically different to us than it did to our ancestors"**

The ability to be so in tune with the dramas of the greater universe was predicated on access to a dark night sky. We as a species came of age through millennia where darkness at night was near total, making the planets and stars easy to spy. Only more recently has our experience of the night changed dramatically. As electricity became widely available and populations became more concentrated in brightly lit urban areas, these dynamics changed.

It is no longer a given that someone will know what the Milky Way looks like. I grew up in the highly polluted Los Angeles of the 1980s and 1990s, where we saw the moon, maybe Venus and often little else.

These limitations are tragic. Not only is air pollution a threat to our bodies, but light pollution is a threat to wildlife by, for example, disrupting the breeding activity of nocturnal animals.

When people miss out on the wonders of the cosmos, they miss out on making a connection that is part of who we are as people.

The majestic telescope images produced by astronomers are also affected by light and air pollution.

Today, the challenges aren't all coming from the ground, where our cars and fireplaces are emitting pollution and our street lamps are making it difficult to see the sky. We now also have to contend with the satellites that we launch into the sky, which can be disruptive to our ability to see the cosmos beyond what is hanging around in low Earth orbit.

Though it can be fun to play spot the International Space Station, with the launch of commercial crewed space flight and poorly regulated, billionaire-owned satellite constellations, the night sky may forever look dramatically different to us than it did to our ancestors. Ostensibly, the humanist argument for launching tens of thousands of satellites into space is that they can provide internet to rural areas. However, an alternative approach would be to tax billionaires to fund on-the-ground infrastructure.

As of now, these constellations are such a radical transformation to the night sky that astronomers are hosting meetings about how to deal with the damage they are projected to do to observational astronomy. It's easy to argue that these artificial satellite constellations are part of a necessary technological advance. But I have to wonder what it means to forever change the sky, leaving our ancestral heritage more difficult to recognise. ▮

Chanda's week

What I'm reading

I recently grabbed a copy of A. Zee's Fly By Night Physics: How physicists use the backs of envelopes.

What I'm watching

I finally saw the film Arrival *– it was very good.*

What I'm working on

I am teaching an introduction to stellar astrophysics this autumn, so I am doing lots of preparation!

This column appears monthly. Up next week: Graham Lawton

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Editor's pick

On the transition to a greener energy world

7 August, p 34

From Robert Deuchar,
Milton Keynes, Buckinghamshire, UK

In your extended look at how to transform our energy system to a climate-friendly one, nuclear power doesn't make the cut.

It should. For starters, Rolls-Royce is leading a consortium to produce small modular nuclear reactors producing about 450 megawatts each. It says that they could be operating in the early 2030s at a cost comparable with renewables such as wind.

In addition, you report a "lack of public and political support" for nuclear, but another technology, thorium-powered nuclear, may offer a way to address this. This is inherently safe as the reaction needs a beam of neutrons, so if there is a problem the beam can be turned off.

The public should be persuaded that thorium can be a major electricity generator in the medium term. Relying on wind and solar is putting all your eggs in one basket. Four major sources would be good: wind, solar, modular (uranium) nuclear and thorium nuclear.

From Peter Wallace,
Guildford, Surrey, UK

The future widespread use of electric cars is an unthinking assumption. Cars are a particularly inefficient mode of transport. Most spend 90 to 95 per cent of the time parked in driveways, car parks and on the road. A traffic jam of electric cars will still happen.

A mix of public transport, cycleways and footpaths would be far more efficient and better for our health and wallets. Electric cars could be rented when needed. A debate on sustainable transport policy is long overdue.

From Eric Kvaalen,
Les Essarts-le-Roi, France

There has long been a negative stance on biofuels, but they don't have to be made from food crops. They can be made from any kind of plant. The main rivals to power transport – batteries for electric vehicles – are not only heavy, but entail an environmental and human cost in production. For example, a source of cobalt involves child labour in the Democratic Republic of the Congo.

Biofuels can be produced in a carbon-neutral way. They are also much more sensible than building devices to remove carbon dioxide from the air to squeeze into aquifers or try to turn into fuel.

From Merlin Reader, London, UK

Whatever we do with our energy systems, it is too late to prevent sea level rise. We have to accept that Jakarta, Miami, Bangkok and many other cities, including London's riverside within the next 50 years, are lost causes. While wealthy elites can afford to flee, for billions of poorer people across the globe, we will need solutions.

From Brian Pollard,
Launceston, Cornwall, UK

The best source of energy we have is the sun and the right place to put solar generators is in hot deserts, where solar strength is great and pretty constant all year.

Such a scheme was proposed and costed in 2010 in order to supply energy from North Africa to Europe. It was shown to be feasible, with a tried and tested power station prototype, which has the ability to supply electricity 24/7, and at a remarkably modest cost.

Bitcoin computers could be turned to climate science

31 July, p 11

From Andy Prior
Malvern, Worcestershire, UK

You report climate scientist Tim Palmer's call for a "CERN for climate change" supercomputer project. Why not incentivise the vast computing resources of the cryptocurrency mining community to perform the calculations? Although most mining hardware is targeted at cryptocurrency solutions, this could be addressed.

Palmer cites €200 million a year as a likely running cost for the climate computer he envisages, the equivalent of about 15 bitcoin per day. Any bitcoin mining group that is performing worse than that, but could meet the atmospheric modelling need, ought to be considering switching business models. There are several "green" mining organisations that might be attracted to the idea that their contribution to the global carbon footprint is at least being targeted at solving the problem.

Australia's climate impact isn't so great

Letters, 31 July

From Graham Keith,
Warrnambool, Victoria, Australia

Ian Napier writes that Australia isn't responsible for climate damage because its carbon emissions are less than 2 per cent of the world's total. This can't be justified when it is known that its population is only about 0.33 per cent of Earth's. Its annual export of some 400 million tonnes of coal only adds to the flames.

Don't let economic growth trash what's left of Earth

7 August, p 23

From Manek Dubash,
Lewes, East Sussex, UK

Jim Watson proposes that there are advantages for many countries to skipping fossil fuels and moving directly to renewable energy supplies. I'm sure he's right about that. He then says that this switch could underpin economic development. But is it not the case that economic development – in other words, more consumption of finite planetary resources – is the driver behind the greatest and fastest extinction of other species?

Rather than viewing economic development as inevitable, maybe a better solution would be to create and promote economic models that avoid replicating the mess so-called developed countries have made.

Another explanation for breathing easier at altitude

31 July, p 42

From Peter Slessenger,
Reading, Berkshire, UK

You report suggestions that asthma could be reduced in a lower oxygen atmosphere. There may be a simpler explanation – a controlled or high-altitude atmosphere may lack the irritants that provoke shortness of breath.

Several years ago I went on holiday in North Wales. I climbed Snowdon, Pen yr Ole Wen, Carnedd Llewelyn, Cadair Idris and several other peaks before realising that I hadn't taken either of my asthma inhalers for five days. The air in North Wales being so much cleaner than in Reading, I felt much healthier than normal.

The air at higher altitudes often lacks the noxious fumes from car and truck engines and pollen from many sources. So maybe the experiment could be repeated with people in a really clean air environment and 21 per cent oxygen as a control, and then a dirty, low-oxygen environment. ▮

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT will be delayed

For the record

▮ In our recent feature on cave art (31 July, p36), the depiction of a kangaroo shown on page 39 was in fact ancient aboriginal rock art at Kakadu National Park, Australia

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> Dr Sunay Usluer, Janet Thornton Felllow

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>
> Eugene Gardner, Postdoctoral Fellow

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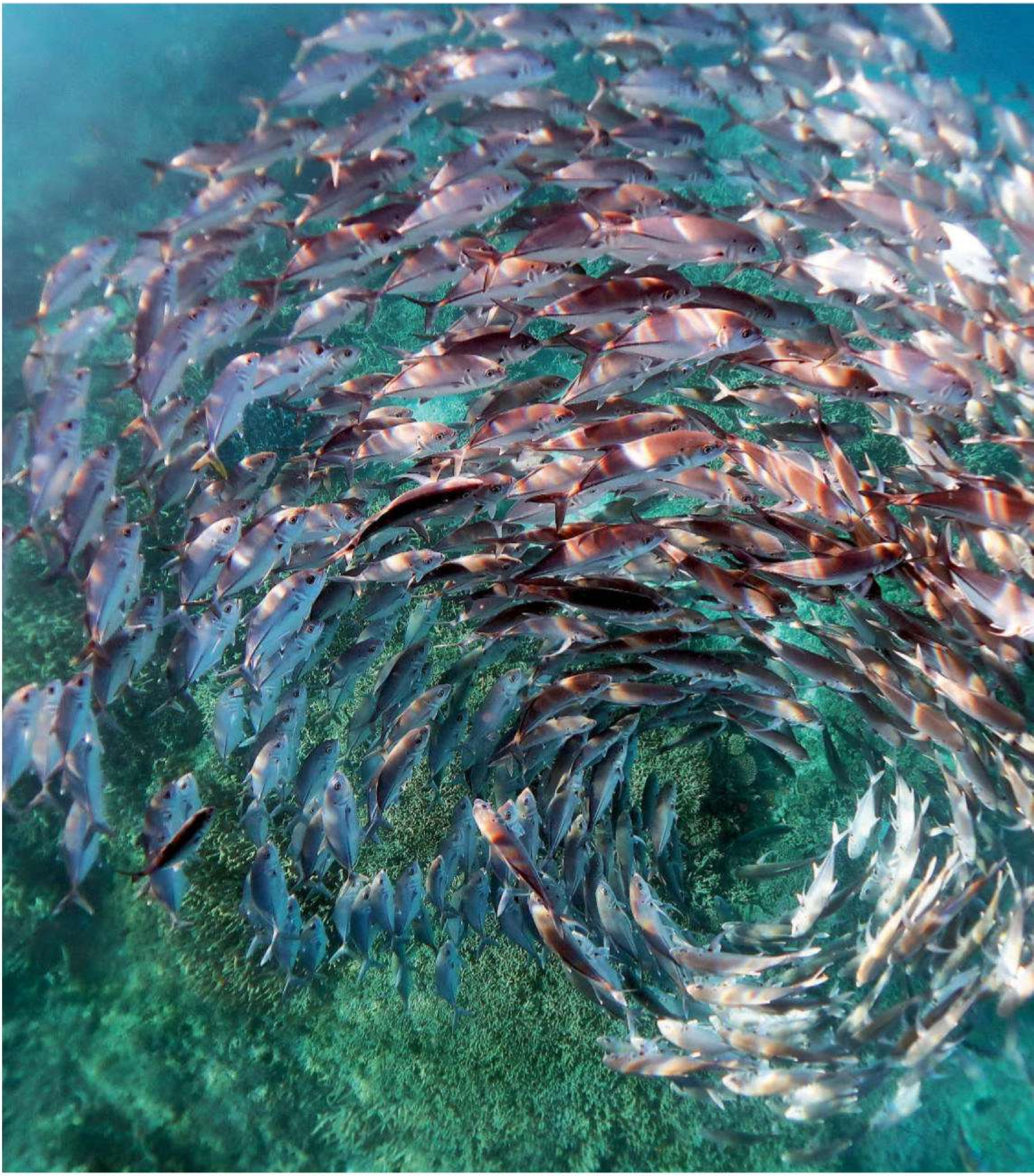
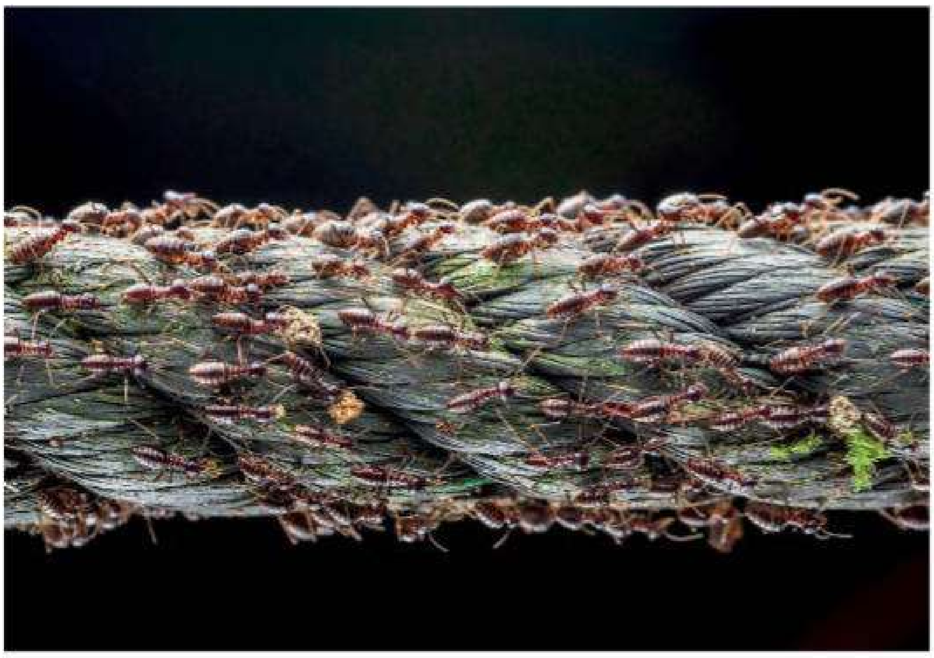
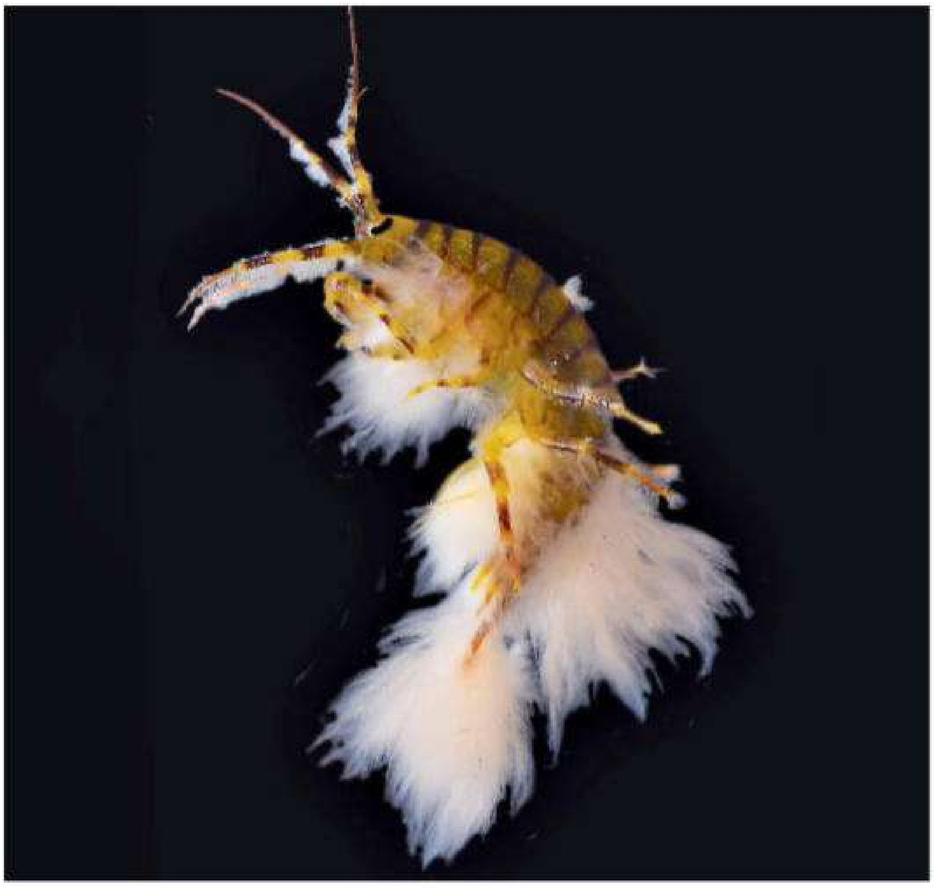
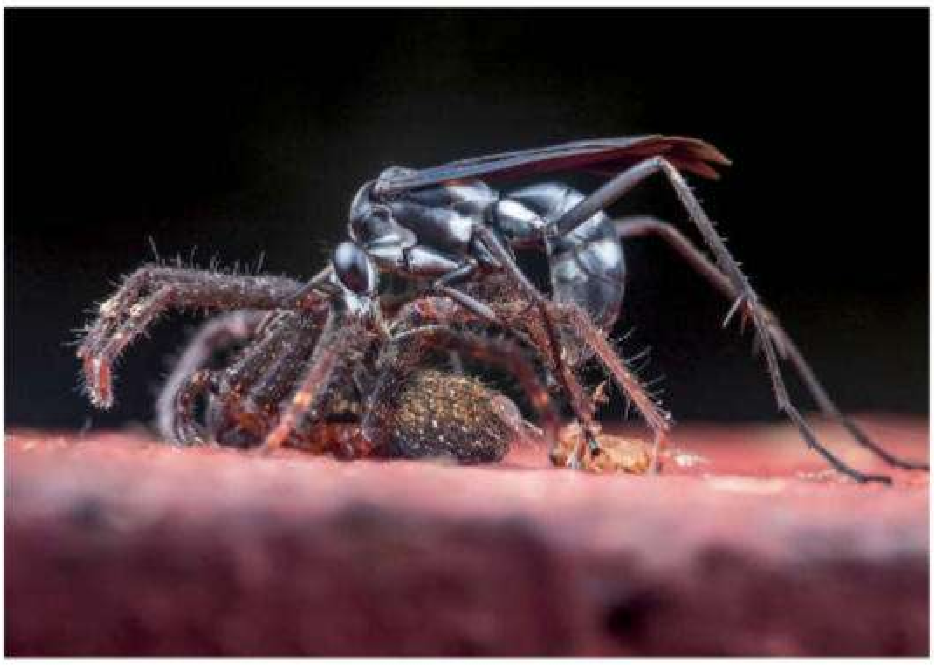








Nature's range

THIS stunning selection of images showcases the world's biodiversity to highlight the importance of protecting it. The pictures represent some of the winners and runners-up of this year's *BMC Ecology and Evolution* photography competition, which invited researchers to submit images that they think encapsulate the diversity of animals and plants.

The main image is the overall winner, taken by coral reef ecologist Kristen Brown. She captured this school of jack fish at Heron Island in Australia's Great Barrier Reef, and describes the scene as a metaphor for the climate change, pollution and overfishing crisis spiralling out of control in and around the world's oceans.

On the near left (from top to bottom), the winning image in the Population Ecology category by evolutionary biologist Roberto García-Roa shows soldier termites using an abandoned rope to migrate across a forest in Malaysia.

Kseniya Vereshchagina, an ecologist who studies Lake Baikal in Siberia, was the overall runner-up for her image of *Eulimnogammarus verrucosus* with a fluffy parasitic infection. Heavy industry and tourism in the lake weakens the immunity of these crustaceans, making them more susceptible to such things.

The winning image in the Behavioural Ecology category was also taken by García-Roa, and shows a wasp capturing a spider on the wall of a biological station in Ecuador. ▮

Gege Li

Can we model the world?

We can forecast everything from traffic flow to human migration, shows a new book. But will the predictions ever win us over, wonders **Simon Ings**

Book

Atlas of Forecasts: Modeling and mapping desirable futures
Katy Börner
MIT Press

MY LEAFY, fairly affluent corner of south London has a traffic congestion problem, and to solve it, there is a plan to close certain roads. You can imagine the furore: the trunk of every kerbside tree sports a protest sign. How can shutting off roads improve traffic flows?

German mathematician Dietrich Braess answered this question back in 1968, showing that adding a road to a network can actually increase travel times due to a boost in drivers using the same routes and therefore increasing traffic. Now a new book, *Atlas of Forecasts: Modeling and mapping desirable futures* by Katy Börner, uses it as a fine example of how a mathematical model predicts and can be used to resolve a real-world problem.

This and more than 1300 other models, maps and forecasts are referenced in Börner's latest atlas, the third to be derived from Indiana University's travelling exhibit Places & Spaces: Mapping science.

Her first, *Atlas of Science: Visualizing what we know* revealed the power of maps in science, while the second, *Atlas of Knowledge: Anyone can map*, focused on visualisation. In her latest foray, Börner wants to show how models, maps and forecasts inform decision-making in education, science, technology and policy-making.

It is a well-structured, heavyweight argument, supported by descriptions of more than 300 applications. Some entries, like Bernard H. Porter's *Map of Physics* of 1939, earn their place purely because of their beauty and the insights they offer. Mostly, though, Börner chooses models that were applied in practice and made a positive difference.

Her range is impressive. We begin at equations, revealing that Newton's law of universal gravitation has been applied to human migration patterns, and move through the centuries. We tip a wink to Jacob Bernoulli's 1713 book *The Art of Conjecturing* – which introduced probability theory – and James Clerk Maxwell's 1868 paper "On governors", which was an early nod towards cybernetics. Finally, we arrive at our current era of massive computation and ever-more complex model building.

It is here that interesting questions start to surface. To forecast the behaviour of complex systems, especially those that contain a human component, many current researchers reach for agent-based modelling (ABM) in which discrete autonomous agents interact with each other and with their common (digitally modelled) environment.

> **"What happens when a model reaches such complexity that only an expert can understand it?"**

But, warns Börner, "ABMs in general have very few analytical tools by which they can be studied, and often no backward sensitivity analysis can be performed because of the large number of parameters and dynamical rules involved". In other words, an ABM model offers us an exquisitely detailed forecast, but no clear way of knowing why the model has drawn the conclusions it has – a risky state of affairs, given that its data came from foible-ridden humans.

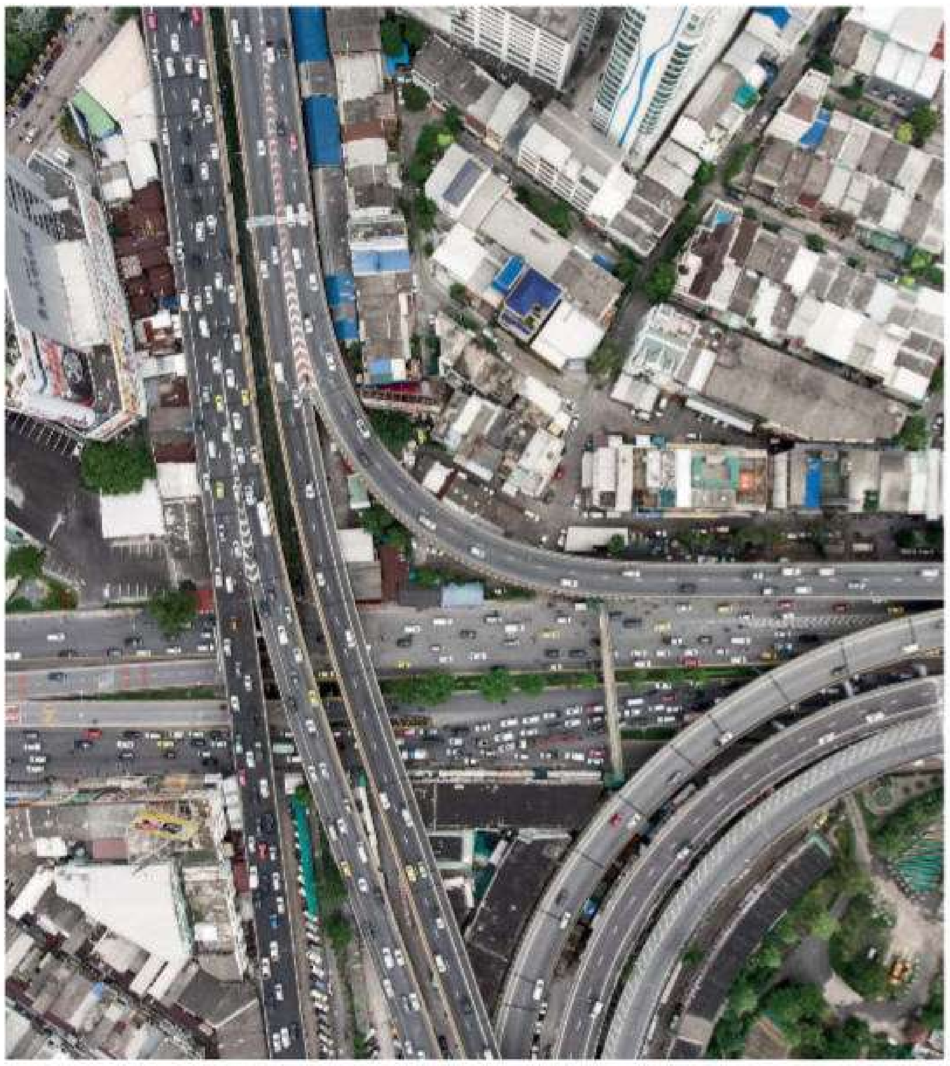
Her sumptuous, detailed book tackles issues of error and bias head-on, but she left me tugging at a different problem, represented by those irate protest signs smothering my neighbourhood.

In over 50 years since Braess's research was published, reasonably wealthy, mostly well-educated people in comfortable surroundings have remained ignorant of how traffic flows work. So what are the chances that the rest of us, busy and preoccupied as we are, will ever really understand, or trust, the other models that increasingly dictate our civic life?

Börner argues that modelling data can counteract tribalism, misinformation, magical thinking, authoritarianism and demonisation. I can't for the life of me see how. What happens when a model reaches such complexity that only an expert can understand it, or when even the expert can't be sure why the forecast is saying what it is saying?

We have enough difficulty understanding climate forecasts, let alone explaining them. To apply these technologies to the civic realm begs a host of problems that are nothing to do with the technology, and everything to do with whether anyone will listen. ▮

Simon Ings is a writer based in London



SASILSOLUTIONS/GETTY IMAGES

Counter-intutively, more roads doesn't mean shorter journeys

Sick in Manaus

A film about a security guard who contracts a mystery fever is strangely compelling, says **Gregory Wakeman**

Film

The Fever

Maya Da-Rin

Select cinemas, UK; Curzon Home Cinema; BFI Player

NEW WAVE FILMS

Justino (left, played by Regis Myrupu) gets a strange fever that doctors can't diagnose

THE opening shot in *The Fever* is a perfect summation of what makes co-writer and director Maya Da-Rin's feature film debut so mesmerising and unique. Over a black screen, we hear a cacophony of crickets and birds, suggesting we are in the heart of nature. Instead, the film cuts to unveil Justino (Regis Myrupu), a 45-year-old security guard dressed in a hard hat and orange high-vis jacket in front of a gigantic metal container.

He stares down the camera, then closes his eyes as the sounds of the trucks and ships at the port where he patrols quickly eclipse the hypnotic noise of the animals and insects.

The widowed Justino lives in the city of Manaus, Brazil, with his daughter Vanessa (Rosa Peixoto), a nursing technician who learns that she has received a scholarship to study medicine at the University of Brasilia, more than 2000 kilometres away.

Vanessa questions whether she should leave her father. Justino is struggling at work and is so overwhelmed by visions of his childhood in a small village in the remote Upper Rio Negro region of the Amazon that he develops an undiagnosable fever. At the same time, a mysterious creature is causing havoc in their neighbourhood.

***The Fever* is undeniably a challenging watch. That is far from a criticism, although it does mean you have to try that little bit harder to fully invest in the slow-burning drama. Da-Rin deploys the patience and confidence of a much more seasoned director as she gradually depicts the everyday struggles of Justino's routine.**

Not that we ever see Justino erupt with anger. One of the most captivating elements of *The Fever* is just how gentle and ruminative its characters are: the silences and glances make the film brim with empathy.

Da-Rin's decision to use Indigenous actors from the Upper Rio Negro, most of whom are first-time actors who belong to the Desano, Tucano and Tariana peoples, brings an authenticity, detail and insight into the culture that makes the film more compelling.

This also means that watching Justino prepare a meal, tell his grandchild a parable and serenely rest in his hammock can be both simple and extremely evocative. It makes it all the more heartbreaking to watch him slowly unravel, a process that Myrupu portrays in a measured and deliberate way.

It's not just the ensemble cast and Da-Rin's direction that makes *The Fever* so watchable. Barbara Alvarez's precise cinematography finds beauty and poetry in even the most mundane settings throughout the film.

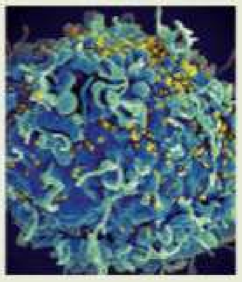
However, it is Felippe Schultz Mussel's work on the sound that really elevates *The Fever*. Not only does he make sure that the timid enunciations of the characters have power, but he juxtaposes and combines the sounds of nature and of the city in a subtle, resonant manner that is captivating.

Sadly, the film does have its issues: occasionally the pacing is just that little bit too slow, or the characters' problems are too vague and understated. However, Da-Rin ties everything up with a thoughtful and genuinely moving final shot.

Not only does *The Fever* encompass timely themes of mental health, family and the effects of capitalism, but its ending is so perfect it may even provoke you to question your own priorities and life choices. ▮

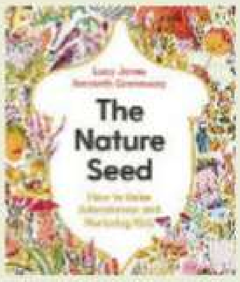
Gregory Wakeman is a film critic based in Philadelphia

Don't miss



Watch

Are viruses alive? asks *New York Times* science columnist Carl Zimmer in this Royal Institution talk. Can viruses and other difficult to pin down microbes help us answer the question: what is life? Streaming live on 26 August at 7pm BST.



Read

The Nature Seed by Lucy Jones and Kenneth Greenway is a handy guide to raising adventurous, nature-loving children, full of fires, potions, foraging and make-believe. Discover the awe in a humble cracked pavement or your local park.

Watch

Jamming the Signal is a live conversation at FACT Liverpool on 28 August from 2pm BST that asks whether social media and instant messaging can be used to effect meaningful change in an age of digital unrest. It will also be streamed online.

T: STOCKTREK IMAGES/ALAMY; B: OXINOXI/GETTY IMAGES PRESS

Secrets and lies

A gripping new drama set in a wellness retreat offers an opportunity to unwind, but the science takes a back seat, says **Gege Li**

TV

Nine Perfect Strangers

Created by David E. Kelley and John Henry Butterworth

Amazon Prime Video

WHEN your life is falling to pieces, what solutions might you seek to get yourself out of that dark place – and how far are you willing to trust someone who seems to have all of the answers?

Nine Perfect Strangers, a new eight-part series based on the book of the same name by Liane Moriarty, inhabits some of this difficult territory. It is rooted around ideas like the possibility of curing depression with spiritual rituals and mindfulness. The miniseries doesn't exactly provide answers on what does and doesn't work or the science behind it, but it is a gripping watch nonetheless.

The show follows the journeys of nine people who arrive at health and wellness resort Tranquillum House for a luxury 10-day retreat, away from the stresses of city life. Each guest is seeking an escape from their life for various reasons: Napoleon and Heather Marconi and their daughter Zoe, for example, are still grieving after the suicide of Zoe's twin brother a few years before, glamorous couple Jessica and Ben's marriage is hanging by a thread, while Frances's career as a romance novelist looks to be heading for the rocks.

Tranquillum House is run by Masha (an ethereal Nicole Kidman) and her assistants Yao (Manny Jacinto) and Delilah (Tiffany Boone). Its big promise is to take the guests on a transformative, healing journey, with Masha assuring them that "when you leave here, you will not be the same person as you are now".

Some of the guests are less than convinced. "Wellness retreats – just another construct to separate rich people from their money and get them to feel good about themselves in the process," says Lars (Luke Evans), another guest who has recently gone through a break-up – although it turns out that he has other motives for joining the retreat.

Things become even more complicated when we discover that the compelling yet shadowy Masha, once consumed by a life of working and partying, set up Tranquillum after being brought back to life by Yao from a gunshot that left her clinically dead.

The retreat's protocol also states that the guests must provide regular blood samples to help tailor their wellness plans and, consequently, the fruit juices and smoothies they are given. Their phones, too, are confiscated on arrival.

But despite the initial unease of many of the group about Masha and her practices, none of them can deny the positive effect of their stay, nor can they quite pull away from the retreat.

> **"The line between fact and pseudoscience is increasingly blurred when it comes to our health and well-being"**

Meanwhile, Masha has started to receive anonymous threatening messages, and more secrets emerge as the treatments the guests receive become more extreme.

The tranquil beauty of the resort and its surroundings are captured by some glorious cinematography (I can't deny that I wouldn't also feel relaxed bathing in a serene river or looking out to the mountains with a tailor-made smoothie in hand).

The acting is outstanding, too. Michael Shannon, for one, is perfectly cast as the constantly upbeat yet quietly suffering Napoleon, while Melissa McCarthy and Bobby Cannavale are both very moving as Frances and former football star Tony, respectively. All of the characters are both likeable and flawed in their own ways.

Nine Perfect Strangers doesn't attempt to challenge the cliché of wellness resorts as places of privilege and indulgence where hard science takes a back seat, and most of the remedies it proposes aren't particularly inspired or surprising.

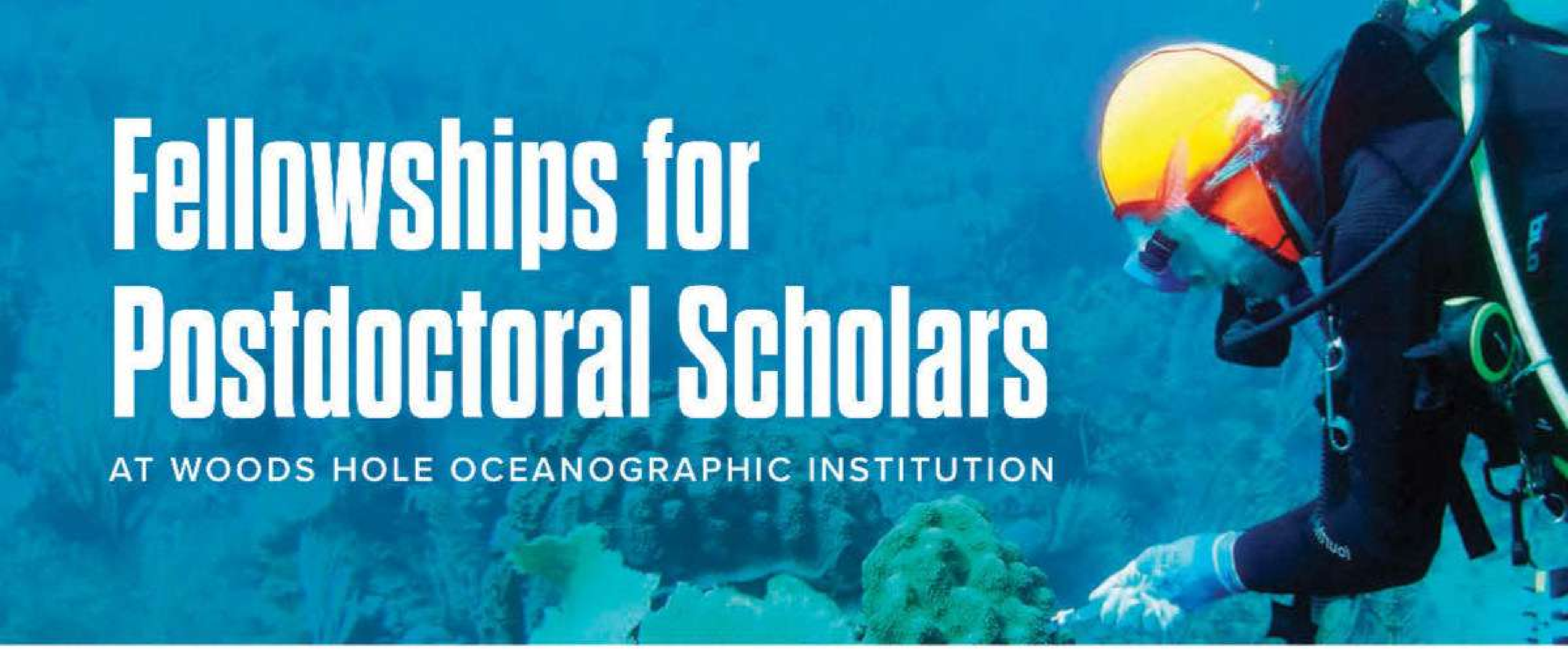
There are some nods to science in the treatments, for example, when the guests take part in activities centred on laughter or fun (known to relieve stress and pain), or when microdosing psilocybin (being explored experimentally) is proposed as a way to help the guests overcome their issues. But the superficial explanations of Masha's healing protocols end up seeming dismissive of proven practices.

To judge from the first six episodes, *Nine Perfect Strangers* is a worthwhile watch for drama, thrills and even some humour. Just don't count on it to challenge your notion of health and wellness retreats or to provide much scientific enlightenment. ▮

Gege Li is a writer based in London

2021 HULU

Nicole Kidman plays the mysterious Masha, who runs a wellness retreat



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- **BIOLOGY**

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Criteria for awards include demonstrated research independence, productivity and novelty, and community service including contributions to making ocean sciences and engineering more diverse, equitable and welcoming. Scholarships are awarded for 18-month appointments ($63,300 stipend per year; health and welfare allowance; and a modest research budget). Recipients are encouraged to pursue their own research interest mentored by resident staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. **COMPLETED APPLICATIONS MUST BE RECEIVED BY OCTOBER 15, 2021**, to start any time after January 1, 2022 and before December 1, 2022. Awards will be announced in December.

Further information about the Scholarships and application forms as well as links to the individual Departments and their research themes may be obtained at:

https://go.whoi.edu/pdscholarship

A goal of the Postdoctoral Scholar Program is the long-term broadening of participation in ocean science and engineering; women, minorities, veterans, those with disabilities, and other underrepresented groups are encouraged to apply.

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The other cradle of humanity

New evidence shows our ancestors didn't just come out of Africa, they also came out of Arabia, as **Michael Marshall** discovers

THE Rub' al-Khali is both desert and deserted – a landscape of reddish sand dunes that stretches as far as the eye can see. This hyper-arid region in the south-east of the Arabian peninsula is approximately the size of France. Parts of it often go an entire year without rain. Almost nobody lives there; its name means "empty quarter".

The rest of Arabia is less environmentally extreme, but still a very tough place to live without air conditioning and other recent technologies. However, the peninsula wasn't always so parched. A mere 8000 years ago, it was wet enough for there to have been many lakes. The same was true at intervals throughout the past million years, when rivers criss-crossed Arabia, forming green corridors where lush vegetation and wildlife flourished amid the sand dunes. For much of recent geological time, the peninsula was at least partly green.

Arabia's verdant past is no mere factoid: it suggests that the region was habitable at times in the distant past. That realisation has prompted archaeologists to start looking for evidence of occupation by humans, their ancestors and their extinct relatives. In just a decade, they have found countless sites where these hominins lived, stretching hundreds of thousands of years into the past. Arabia, it seems, wasn't a mere stopover for hominins as they moved out of Africa into the wider world. It was somewhere they settled for long stretches of time. Indeed, many researchers now think Arabia should be thought of as part of a "greater Africa", and that the peninsula played an important role in human evolution and expansion across the world.

For decades, Africa has been seen as the cradle of humanity. The oldest known hominins arose there around 7 million years ago and stayed on the continent for a long time, evolving into various forms including those that gave us famous fossils such as Ardi and Lucy. While some groups started to wander further afield from about 2 million years ago, Africa remained central to our story. The earliest known remains of our species, *Homo sapiens*, also known as modern humans, are from Africa. There we emerged around 300,000 years ago, and there we pretty much remained until around 60,000 years ago, when a single out-of-Africa migration carried modern humans all around the world – or so anthropologists thought.

"We had a very straightforward scenario," says Michael Petraglia at the Max Planck Institute for the Science of Human History in Jena, Germany. On this reading, Arabia was a mere pit stop for modern humans as they power-walked into Europe, Asia and elsewhere. "It was just on the route out of Africa," says Huw Groucutt at the Max Planck Institute for

SHUTTERSTOCK/HANY MUSALLAM

The Rub' al-Khali desert was inhabited 80,000 years ago or more

Chemical Ecology, also in Jena, Germany. "Some people even said there was no prehistory in Arabia."

As a result of these assumptions, until recently almost nothing was known about hominins in Arabia. Some spectacular rock art sites had been found, but they were 10,000 years old at most (see "Ancient art of Arabia", page 38). Then, a decade ago, a loose coalition of researchers began looking for evidence of earlier occupation, in projects like Petraglia's Palaeodeserts and another called DISPERSE. "We sort of all came together at the right time," says Eleanor Scerri, also at the Max Planck Institute for the Science of Human History.

A crucial driving force was the growing understanding of prehistoric climate change. Over the past few decades, palaeoclimatologists have used records such as deep-sea sediments and ice cores to figure out what the climate was like long ago – and climate modellers have laboured to understand these shifts. These efforts revealed that throughout the past 2.5 million years – the period when there has been permanent ice at both poles – Earth's average temperature has yo-yoed up and down. Cooler periods called glacials saw ice sheets advance from the poles, while warmer interglacials saw them retreat. These cycles affected conditions in Arabia, as well as the neighbouring Sahara in Africa. During interglacials, the monsoon rains shifted north so that these areas were far wetter than they are now – only to become burning desert again during glacials, when the rain returned south.

> "Until recently, almost nothing was known about hominins in Arabia"

To Petraglia and his colleagues, this suggested that Arabia had many rivers and lakes in the wetter periods, so they began looking for them. "Lo and behold, the first season we went to some of these places where we thought we had ancient lakes – bam! – we hit them," he says. The first was the site of Jebel Qattar 1 in what is now the Nefud desert of Saudi Arabia. In 2011, they described finding the remains of a lake, mostly concealed by wind-blown sand, that measured at least 4 kilometres by 20 kilometres. In the 75,000-year-old sediments they found evidence of grasses and trees – along with stone tools indicating that hominins had lived there.

Since then, Petraglia's team and others › have published many similar findings (see map, right). "We now know there are about 10,000 palaeolakes of Arabia," he says. "We've only been to a couple of hundred. On 70 per cent of those we found fossils or archaeology." Hominins even lived in what is now the Rub' al-Khali desert. At Mundafan Al-Buhayrah, a flat region that was once a lake, the team found stone tools dating from between 100,000 and 80,000 years ago.

Occupations tended to follow climatic fluctuations: hominins came in when the climate was wet, and either left or died out when it dried. "This cyclicity is key to everything," says Petraglia. Even the wet periods were no picnic, says Groucutt. "During those periods of much more rainfall, it would have been extremely seasonal." Nevertheless, conditions were wet enough for hippopotamuses to have inhabited the peninsula. "Hippos need perennial water, metres deep," says Groucutt.

Another discovery is that the geography of Arabia had powerful effects on the communities living there. Those residing in northern Arabia probably still had contact with populations in Africa and elsewhere, says Groucutt. This is reflected in the similarities between the stone tools they made. In contrast, the inhabitants of southern Arabia tended to develop distinctive tools, suggesting they were isolated.

But who were these people? Despite the abundance of stone tools, hominin bones have been lacking. That's because the desert isn't well suited to preserving them, says Scerri. "It's hyper-arid, you get windstorms, sediments crumble."

That hasn't stopped some people from speculating. In 2011, Hans-Peter Uerpmann at the University of Tübingen in Germany and his team had claimed that *H. sapiens* were in the region around that time. The assertion was based on stone tools found at Jebel Faya in what is now the United Arab Emirates, dating from between 125,000 and 40,000 years ago, which look similar to tools made by modern humans living in Africa at the time. But there were no bones.

Then, in 2018, a team that included Scerri,

Ancient art of Arabia

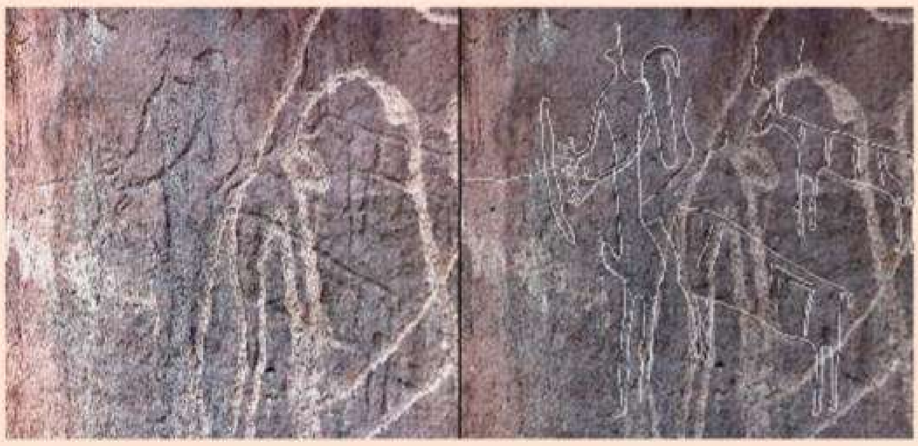
Human ancestors have inhabited the Arabian peninsula for hundreds of thousands of years, at times when the climate was wetter there. Much of the evidence of their presence has eroded away. However, beginning around 10,000 years ago there is a rich record of prehistoric art and artefacts. This tells a story of societies and environments in flux.

Older rock art often shows people hunting wild animals, but later pieces tend to show herding. In many places, older art has been partially overwritten, with artists keeping the human figures but replacing the animals. "There's clearly a cultural memory, almost a dialogue between these hunting scenes and pastoral scenes," says Maria Guagnin at the Max Planck Institute for the Science of Human History in Jena, Germany.

Rock art also reveals the changing fauna of the region. Images at Shuwaymis in north-west Saudi Arabia, dating from more than 8000 years ago, suggest that prey animals, including large carnivores, were abundant. Here, and at a second Saudi Arabian site called Jubbah, there are paintings of people living alongside lesser kudu – a type of antelope that today inhabits the forests of east Africa – and possibly aurochs, the wild species from which cattle were domesticated.

At the Camel Site in northern Arabia, artists carved life-size camels and other animals into rock (see page 40), in most cases more than 8000 years ago. "They look like sculptures coming out of the rock," says Guagnin. Many people must have been involved in their creation: raw materials for tools had to be brought in from 30 kilometres away, and the sculptures are so high that scaffolding may have been needed. "We think there was a lot of communal effort," she says.

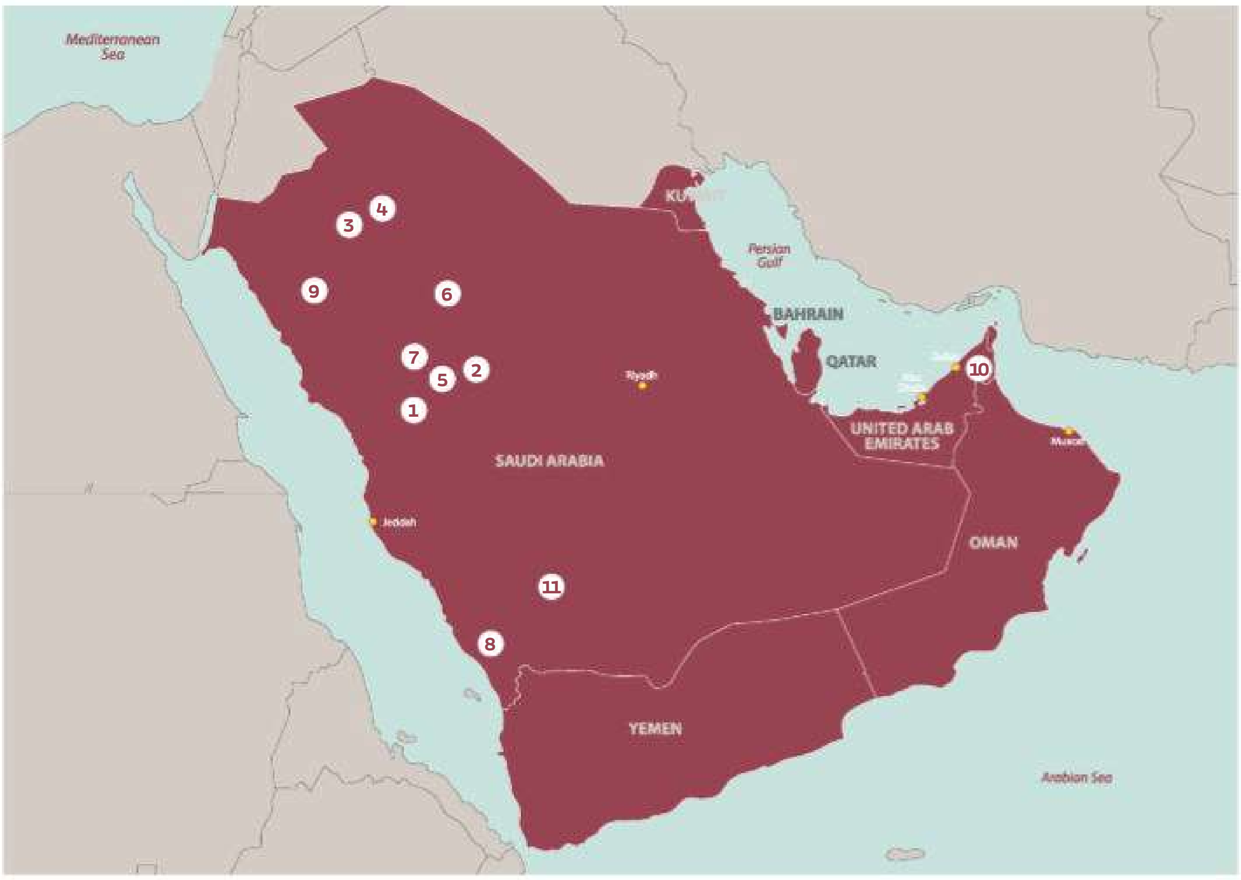
The same is true for mustatils, huge stone monuments in which low walls surround a central courtyard. More than 1000 of these have been found in the north-west of Saudi Arabia, and some are over 7000 years old, making them older than Stonehenge and the pyramids of Egypt. Each one clearly represents a major group effort. Guagnin suspects that people moved around for most of the year, but at the end of the wet season, food may have been abundant enough for them to gather. "There was feasting or maybe even collecting of trophies, so these were big symbolic events and it was important for people to meet up," she says.



MARIA GUAGNIN & HUW GROUCUTT/PALAEODESERTS PROJECT

Into Arabia

Evidence unearthed in the past decade reveals that hominins were living in Arabia up to 500,000 years ago, and spent long periods there at times when the climate was wetter and the environment lusher



1 Shuwaymis 8000-year-old rock art
2 Jubbah 8000-year-old rock art
3 Camel Site 8000-year-old giant rock reliefs
4 Jebel Qattar 1 75,000-year-old paleolake
5 Al Wusta 85,000-year-old *Homo sapiens* finger bone
6 An Nasim 300,000-year-old stone tools
7 Ti's al Ghadah 500,000-300,000-year-old stone tools
8 Wadi Dabsa Palaeolithic stone tools
9 Alathar palaeolake 121,000-112,000-year-old hominin footprints
10 Jebel Faya 125,000-40,000-year-old stone tools
11 Mundafan Al-Buhayrah 100,000-80,000-year-old stone tools

> "If hominins were living in Arabia 500,000 years ago, they were almost certainly not modern humans"

Groucutt and Petraglia got lucky. At Al Wusta in the Nefud desert in northern Saudi Arabia, in the remains of yet another lake, they found a single finger bone. "The day we found that, none of us could really believe it," says Scerri. It was fortuitous, says Groucutt, because finger bones vary a lot between hominins. This one bone was enough to identify the species: *H. sapiens*. And it was 85,000 years old.

First settlers?

That's a clincher, but there is reason to believe that *H. sapiens* were in Arabia before then. Just last year, Petraglia and his colleagues claimed that a set of footprints made between 121,000 and 112,000 years ago at Alathar palaeolake in Saudi Arabia belonged to modern humans. Footprints aren't always identifiable, but "we have had no flak on our interpretation", says Petraglia. In any case, people had time to reach Arabia to make the footprints: the oldest remains of modern humans found so far are from Jebel Irhoud in Morocco, and are between 250,000 and 350,000 years old. Furthermore, modern human remains dating to 210,000 years ago have been found in Greece, and a jawbone found in Israel dates to at least 177,000 years ago.

Although the 85,000-year-old Al Wusta finger bone is still the only known hominin bone found in Arabia, the stone tool record goes back much further. Stone tools found at An Nasim in Saudi Arabia are 300,000 years old. And, in 2018, a team including Petraglia, Scerri and Groucutt described their discoveries at Ti's al Ghadah, also in Saudi Arabia. There, a dried-up lake was once surrounded by fertile grasslands, inhabited by elephants, Asiatic wild asses and water birds. Some of the animal bones seem to have cut marks and other signs of hominin activity – and there were stone tools. The animal remains were dated to between 300,000 and 500,000 years ago.

If hominins were living in Arabia 500,000 years ago, they were almost certainly not modern humans. Many other hominins were roaming Eurasia at that time (see "Possible Arabians", page 40), but the prime suspects are the Neanderthals. "I am pretty sure Neanderthals were there, at least in the northern parts of Arabia," says Scerri. She notes that Neanderthal remains have been found in the Levant, the region to the north of Arabia that includes modern Israel. "We have stone tools in Arabia that are very similar to [ones found in] sites with Neanderthal fossils," says Scerri.

Neanderthals and modern humans probably weren't the only early Arabians. Scerri and many others suspect the region was something of a melting pot, with multiple groups moving in and out as the climate became wetter and drier. "My guess is we're going to be looking at a whole variety of potentially different hominin species, almost all of whom could probably interbreed," says Anthony Sinclair at the University of Liverpool, UK, who is a member of the DISPERSE project.

What does all this mean for human evolution? There are two key questions: how did modern humans use Arabia once they began moving outside Africa, and what role did Arabia play in the prior evolution of *H. sapiens*?

For Petraglia, the discovery of so many hominin sites over such a wide span of time, and with such a close correlation to shifting climate, demolishes the narrative of a single migration by modern humans out of Africa around 60,000 years ago. That idea was already foundering thanks to the growing number of modern human fossils found outside Africa before the supposed migration. But Arabia lends weight to the idea that there were multiple migrations, every time the climate and ecosystems became favourable. ›

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Possible Arabians

Emerging evidence reveals Arabia to have been inhabited from as early as 500,000 years ago. The list of hominins whose eras fit this time span and who may have lived there is quite long.

MODERN HUMANS
Era: 300,000 years ago to present
Our species' core homeland was Africa. The oldest fossil evidence from Arabia is 85,000 years ago, but that is likely to be pushed back as we continue to look for fossils in the region.

NEANDERTHALS
800,000-400,000 years ago to 40,000 years ago
Neanderthals are known from Europe and western Asia, sometimes roaming as far east as the Altai mountains in Siberia. They made it to Israel and may well have gone south into Arabia.

DENISOVANS
800,000-400,000 years ago to at least 43,000 years ago
Denisovans were a sister group of the Neanderthals, known from a handful of sites in east Asia. Evidence suggests Arabia was too far to the west of their homeland – but that may change.

HOMO ERECTUS
2 million years ago to at least 117,000 years ago
The earliest hominin known to have lived outside Africa, *H. erectus*, reached as far east as Java. It seems likely to have inhabited Arabia at times.

NESHER RAMLA *HOMO*
Approximately 420,000 years ago to 140,000 years ago
Only described in 2021, the Nesher Ramla *Homo* may possibly be an ancestor of Neanderthals. It is known from one site in Israel, but could have ventured south.

At the Camel Site in Saudi Arabia, carvings date back around 8000 years

MARIA GUAGNIN/CAMEL SITE ARCHAEOLOGICAL PROJECT

"One model that I've been promoting is a multiple dispersals model of *Homo sapiens* through time," says Petraglia. "Not just one event, but many events and interbreeding as they went along." In this model, the reason genetics points to a significant shift 60,000 years ago isn't a big out-of-Africa migration, but an increase in the overall size of the human population. "In other words, there may be genetic swamping of small populations that were present in Eurasia earlier," says Petraglia. This would create "the illusion" of a single large dispersal, he says.

Accidental migrants

The discoveries in Arabia also show that modern humans didn't stick to the coasts when migrating out of Africa, as has sometimes been suggested. There is no doubt that some did travel that way. For example, Sinclair has found evidence of people living in several sites on Arabia's Red Sea coast, including Wadi Dhahaban and Wadi Dabsa. But, one way or another, the lake finds show that they also crossed the centre of the peninsula.

The migrants would have been small groups of hunter-gatherers, not large populations. There is no reason to think they had a goal in mind. "People weren't aiming for anywhere," says Groucutt. "They were just roaming around and the opportunities changed a bit, the monsoon moved a bit further north, and over time they, by accident, moved."

This points to a deeper and larger message about our evolutionary origins. Arabia is technically part of Eurasia because of a divide in the underlying tectonic plates. But as far as African hominins were concerned, it was all one contiguous landmass – and palaeoanthropologists are starting to see it that way too. "I believe Arabia is part of a greater Africa," says Sinclair.

Scerri goes even further. "Parts of south-west Asia, which are the neighbouring region to Africa, at times probably were part of the core area of human evolution," she says. She has argued for "African multiregionalism", a scenario in which Africa was home to multiple *H. sapiens* populations that were sometimes isolated and sometimes interbred, depending on which regions were liveable. Arabia was one more place early humans could live, making it a part of the melting pot from which humanity emerged.

In other words, we are all ultimately from Africa – it's just that we need to reconsider our notion of where Africa ends. The Arabian landscapes shaped our species as surely as the savannahs, forests and coasts of Africa. The interior of the Rub' al-Khali may be a searing desert today, but once upon a time it was home to our distant ancestors. ▮

Michael Marshall is a science writer based in Devon, UK. His book *The Genesis Quest* is out now

Chill in the air

Taking billions of tonnes of carbon dioxide out of the atmosphere looks crucial to limiting global warming – but does anyone really know how to do it, asks **Adam Vaughan**

PETER CROWTHER

A STAR attraction at the Science Museum in London right now is a tree. Not an elegant product of evolution, but something that looks rather like a steampunk collision of an industrial air-conditioning unit and an accordion. What researcher Klaus Lackner's mechanical tree has in common with the natural variety, however, is that it is great at sucking carbon dioxide out of the air.

We are going to need a lot of that in the coming decades if we are to achieve net-zero carbon emissions by mid-century and so head off the worst of the climate crisis. The key word here is "net". Even when we have wiped out all the emissions we can, intractable sources will remain, from the likes of food production, flying and heavy industry. Negative emissions technologies are intended to bridge the gap – by removing CO_2 already in the atmosphere.

This past year, individuals and companies from Elon Musk to Microsoft and US oil firm Occidental Petroleum have committed significant sums to various schemes to do just that. But they are controversial. Campaigner Greta Thunberg recently derided governments for pinning their ›

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TAKE A LEAF...

One negative emissions technology already exists at scale and usually costs less than $100 per tonne of carbon removed to implement: planting trees. A recent estimate found that Earth has a potential 678 million hectares, twice the size of India, for forest regrowth. That would remove roughly 6 gigatonnes of CO_2 a year. "That's a significant amount," says Simon Lewis at the University of Leeds, UK.

The economic reality, however, is that only a third of that area can probably be affordably planted, he says. Even so, one UN-backed group estimates that nature-based carbon removal alone could be worth more than the world's biggest oil and gas companies by 2040.

Lewis says government pledges of restoring 350 million hectares of forest would scoop up most of the economically attractive tree-planting land, leaving little for the corporate world to cheaply offset its emissions. The potential carbon capture via forest creation cited by oil company Shell, of 11 gigatonnes of CO_2, is "colossal" and "absurd", according to Lewis.

And there are concerns over new forests if done at scale and in the wrong places. Tree planting in inappropriate areas such as savannah could harm biodiversity and food production, says Lewis. He has found that almost half of global forest plans involve monoculture plantations of single species such as eucalyptus, which are poor for wildlife and store less carbon. Planting trees on peatland and carbon-rich soils can cancel out CO_2 savings or even lead to carbon emissions. Another potential downside of trees is that a warming world makes it harder for them to keep the carbon locked up, due to more fires and droughts, says Lewis.

PETER CROWTHER

“Even if carbon removal technologies can be scaled up, there are concerns that the cure might be worse than the disease”

climate plans on “fantasy-scaled” versions of “barely existing” technologies. Even if they can scale up, there are concerns over whether the cure would be worse than the disease, due to potential downsides of negative emissions technology for biodiversity, water consumption, food production and energy use. Time to ask: when it comes to carbon removal, do we really know what we are doing?

As last week’s report from the Intergovernmental Panel on Climate Change (IPCC) made plainer than ever before, we are running out of time to stave off the worst of global warming (see News section). And for all the warm words on climate action, our carbon emissions continue on the up. Last year, even with the pandemic, they amounted to 39 gigatonnes of CO_2. Back in 2014, AR5, the IPCC’s fifth climate science assessment report , reckoned that staying under 2°C of warming – the goal agreed at the Paris climate change summit in 2015, with a lower, desired target of 1.5°C – would mean removing around 730 gigatonnes of CO_2 from the air this century.

That scenario foresaw the heavy lifting – 480 gigatonnes – being done by “bioenergy with carbon capture and storage” (BECCS). This involves planting a crop that rapidly absorbs CO_2 because it grows quickly, then burning the vegetation for energy generation and capturing and storing the resulting carbon emissions. The remainder of the 730 gigatonnes would be removed by planting trees – the original, and for many still the best, negative emissions technology (see “Take a leaf...”, left).

The IPCC’s modelling in the 2014 report was derided by some for requiring impossibly large areas of land for energy crops, as much as two and half Indias in some scenarios. Rob Bellamy at the University of Manchester, UK, says the 480 gigatonnes figure shouldn’t be taken literally – it is a result of models focusing on cost, rather than practicalities. “Nobody is ever going to do that amount of BECCS, it’s ridiculous,” he says.

Only one BECCS facility, in Illinois, is currently storing CO_2, but this decade it could be joined by plants in Japan, Norway and the UK. “The key issue is we are running out of time to hit the 1.5°C target. The case for BECCS is it’s available today,” says Will Gardiner, chief executive of UK energy firm Drax.

Its power station in North Yorkshire once burned coal and was Europe’s biggest CO_2 emitter. It has since started burning biomass, mostly wood pellets shipped from forests in the southern US. That is technically a low-carbon technology, as the CO_2 emitted on burning was only recently absorbed from the air by the trees. Now Gardiner wants to retrofit two of the power station’s units so each captures 4 million tonnes of CO_2 per year.

That would be a significant step towards doing BECCS at scale – the UK’s CO_2 emissions were 326 million tonnes last year. Ultimately, Gardiner and other members of the Coalition for Negative Emissions think there is room for BECCS to eventually remove about 4 gigatonnes of CO_2 a year globally, roughly what aviation emits.

Missing policies

But there are lots of missing pieces for even this single project in the UK. They include financial incentives such as a minimum guaranteed price for the power and a negative emissions payment for storing the CO_2. The UK, like most countries, has no policies specifically to support CO_2 removal. “The incentives landscape is a bit of a black hole when it comes to negative emissions,” says Bellamy. The fact that most of the biomass burnt by Drax comes from trees felled on the other side of the Atlantic, with only a small fraction from crops in the UK, may prove a PR stumbling block too.

Land use impacts are why Bob Watson at the University of East Anglia, UK, a former adviser to the UK government and chair of both the IPCC and the UN’s biodiversity science panel, › has turned against BECCS. “I used to be a real big fan of this. But boy, I think we have to be careful,” he says. Among his fears are fast-growing monocultures replacing biodiverse areas and energy crops impinging on arable land and threatening food security. Recent research also indicates that the irrigation requirements of a mass BECCS roll-out could make water access harder for billions of people.

For such reasons, the next IPCC assessment report, AR6 – whose first part, on the basic science, came out last week – will advocate a portfolio of carbon-removal technologies. “AR5 largely focused on BECCS because that was pretty much all there was. AR6 will look at more technologies and be less simplistic,” says Wil Burns at American University i on Washington DC, who reviews IPCC reports.

The main high-tech rival to BECCS is direct air capture. Typically, this uses fans to draw air into a machine, where chemicals remove the air’s relatively dilute CO_2. Three main players – Climeworks in Switzerland, Carbon Engineering in Canada and Global Thermostat in the US – have been joined by two start-ups, Carbon Collect in Ireland and Heirloom in the US. This is the approach Microsoft and Occidental Petroleum are investing in, and the UK recently created a £100 million competition for direct air capture research.

CLIMEWORKS

Climeworks’ direct air capture plant in Hellisheidi, Iceland, is the world’s largest

Lackner, a professor at Arizona State University whose Science Museum mechanical tree was made in 2017, has been working on the tech since the 1990s. Its advantages, he says, are its small land footprint and easy scalability. But it is elaborate and expensive, for now at least: Climeworks cites a cost of $600 per tonne of CO_2 removed. “The world cannot afford that at 40 billion tonnes [emitted a year],” says Lackner. It also uses a lot of energy. One study projected the machines could account for a quarter of world energy demand by 2100.

Climeworks is now building its 15th plant, but is removing a tiny 6000 tonnes of CO_2 a year. Christoph Beuttler at the firm thinks it can eventually scale up to billions of tonnes and get the cost down to $100 to $250 a tonne through automated mass production. “We are a bit like Tesla when we have built the Roadster, but we are a long way from a Gigafactory for mass production of parts,” he says.

Vexed questions

Carbon Collect is about to deploy commercial versions of Lackner’s tree in Arizona that look a bit like giant Alexa speakers. The company aims to reduce energy costs by dispensing with the fans, creating a purely passive unit where wind blows the air in. The captured CO_2 will initially be sent to an algae farm at Arizona State University, and later sold as a “green CO_2” alternative to hydrocarbon-produced CO_2 for horticulture and other sectors, perhaps for carbonated drinks or making synthetic fuel for planes. Storing the CO_2 will be the next step. “[The storage] market isn’t quite there yet, but it is emerging,” says Carbon Collect’s Reyad Fezzani.

Other ways to remove carbon

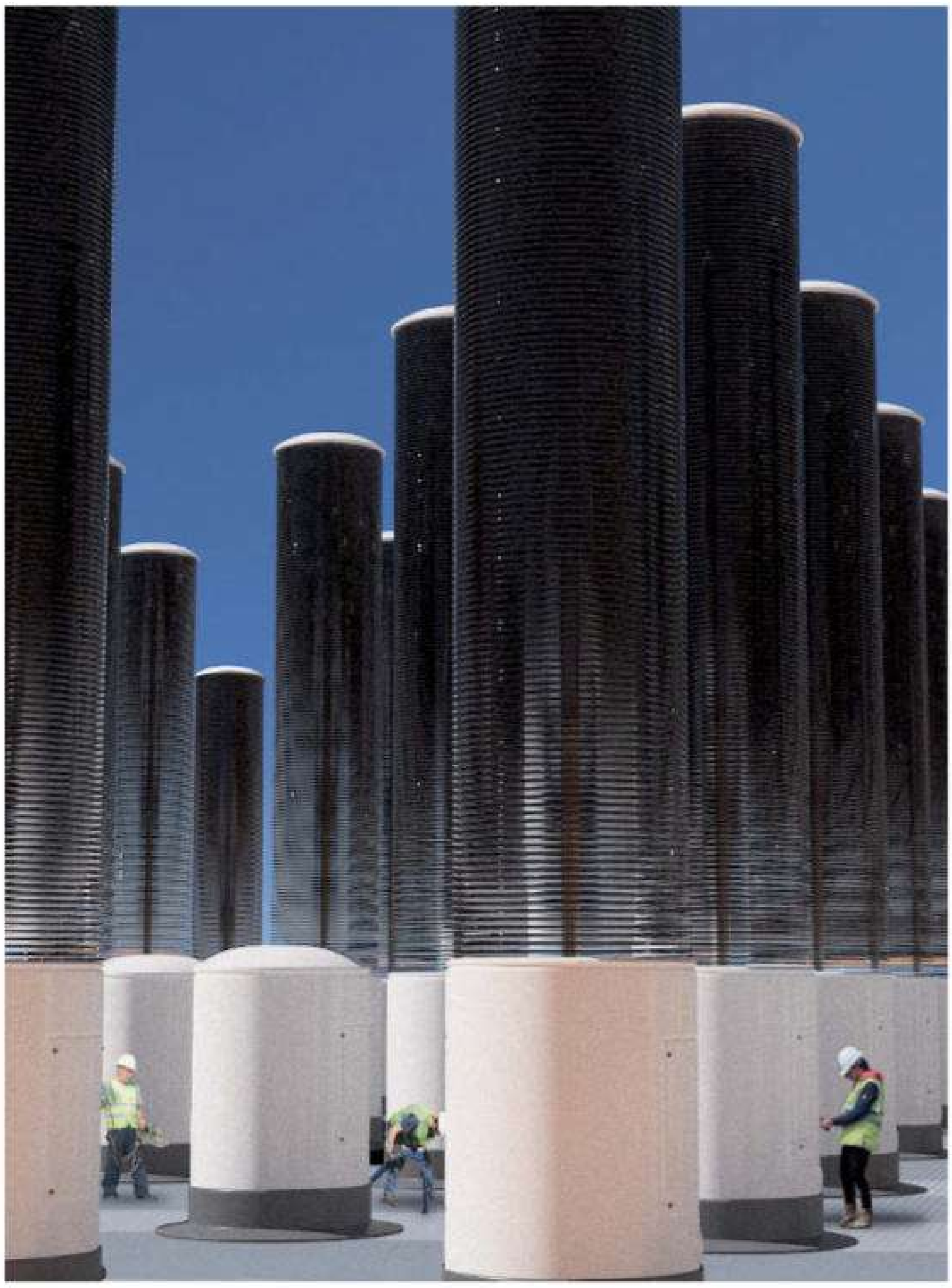
Growing trees, burning biofuels and sucking CO_2 from the air (see main story) aren’t the only ways we might remove our carbon emissions.

ROCK DUST Grinding up rocks to increase their surface area and spreading them on cropland speeds up how rocks absorb CO_2 naturally. Known as enhanced weathering, this could take away between 0.5 and 2 gigatonnes of CO_2 a year by 2050, one team found, and might boost crop yields in the process. But the technique is still at the stage of small field experiments, and there are concerns over rock availability, the energy needed to grind it up and the risk of soil contamination.

ECOSYSTEM RESTORATION Beyond woodlands, many habitats can help remove CO_2 emissions, including seagrass beds, salt marshes and other marine and coastal environments. On land, the biggest potential in the UK comes from restoring and protecting the country’s peatlands.

BIOCHAR This is a carbon-rich charcoal-like remnant made by heating plant waste in an oxygen-free environment, a technique known as pyrolysis. Advocates suggest burying the biochar in soil to lock it away. Like rock dust, there are some signs that it could boost crop yields. Some companies, such as UK-based Carbon Gold, are already producing biochar for gardeners to use, but it is far from clear the approach could scale to removing billions of tonnes of CO_2.

IRON FILINGS Iron fertilises the growth of marine phytoplankton, which absorb CO_2 from the air, eventually locking it away in the ocean. An international team plans to seed three locations across the globe with extra iron to test the effects, although such geoengineering schemes are controversial.



CARBON COLLECT LIMITED

An artist's rendering of a "mechanical tree" farm designed to remove CO_2 from the air

Storage is one of the most vexing questions with both BECCS and direct air capture. Using the removed CO_2 as Carbon Collect proposes may help the climate fight a little by displacing higher-carbon ways of making the gas, but such uses mean it is eventually released back into the air. If we are to remove billions of tonnes of CO_2, the vast majority will need to be locked away. "There are only so many Diet Cokes that need the CO_2," says Burns.

The Drax plan is to build a storage facility in bedrock 1 to 2 kilometres under the North Sea, in old oil and gas fields, with a pipe some 176 kilometres long to connect it to the plant. Others, including Climeworks, are looking to capture CO_2 in basalt rock, a process known as mineralisation. "That could be a game changer. That truly is long-term storage," says Burns.

New economic incentives will still be needed for firms to sit on the CO_2. The US has a tax credit for storing the gas that was recently extended until 2026. Emily Cox at Cardiff University in the UK says that scheme needs to run for longer to incentivise projects, but could still be a model for other countries.

Storage of CO_2 may yet face other obstacles. Plans for an underground facility at Barendrecht in the Netherlands caused protests 12 years ago, and Burns expects to see the rise of the NUMBY – "Not Under My Backyard" – activist, particularly in the US. "If you're going to have millions or billions of tonnes of CO_2 and are storing it, you may well see substantial resistance. Litigation could slow those projects down," he says.

Cox has found people in the UK are generally supportive of research into CO_2 removal, but prefer BECCS over direct air capture. "People favour using plants in the process," she says, because it makes it seem more "natural". But she says it has been hard to communicate the scale of plantations needed for BECCS. "I don't think global north populations have been exposed to the downsides of growing biomass," she says. People in other parts of the world who have seen the ravages of monocultures on biodiverse environments such as rainforests might have different views.

Bellamy says his research shows people do support paying power stations for storing CO_2, as long as it is perceived as part of an overall, coherent package of reducing emissions too. That is a point Watson can't emphasise enough, either: the faster we cut emissions today, the less we will need to rely on sucking huge amounts of CO_2 out of the air. Yet there is no plausible road to limiting the global temperature rise to 2°C, let alone 1.5°C, without negative emissions technologies. Even the International Energy Agency, which is much more conservative on how much CO_2 needs to be removed than the IPCC, thinks 2.4 gigatonnes a year will have to be captured in 2050 by BECCS and direct air capture, with 1.9 gigatonnes of that stored.

Can we get to that scale by mid-century? And can we do that without environmental impacts that could rival those from the catastrophic temperature rises they are meant to avoid? It's possible, but it is a Herculean task, says Burns. "If this really is going to come to fruition, there is going to have to be a tremendous acceleration of efforts." ▮

> **"The faster we cut emissions today, the less we will need to rely on sucking huge amounts of CO_2 out of the air"**

Adam Vaughan is chief reporter for *New Scientist*

Secrets of the lost meteorites

Fossil meteorites are probably the hardest geological treasure to discover. But a spate of recent finds are revealing surprises about Earth's deep history, says **Joshua Howgego**

HE IS more or less over it now, but Birger Schmitz once had an odd habit. He would visit a train station or an airport – any public building with a large expanse of stone floor would do – and shuffle around on his hands and knees, eyes glued to the ground. "I have had problems with security guards," he admits. "If you start crawling around in the dark corners of an airport, people become suspicious."

Schmitz is no terrorist. He is one of the world's foremost hunters of fossil meteorites, ancient extra-terrestrial stones. It so happens that limestone floor tiles are an excellent place to look for them. Others prefer remote Australian deserts or Antarctic ice. But whether your searching ground is mundane or exotic, it is an inestimably difficult task.

Only about two olive-sized meteorites fall on an area the size of Wales each year. Your odds of finding one aren't good even if you know what to look for. Now imagine looking for a meteorite that fell millions of years agobefore being entombed in solid rock like the bones of a dinosaur. It is so difficult that it is almost laughable.

But it isn't impossible. That much has become apparent over the past few years, as fossil meteorite hunters have unearthed them, first in dribs and drabs, then in huge numbers. It turns out they have a unique story to tell: contemporary meteorites tell us about how the solar system grew into its current form. Fossil meteorites, on the other hand, hold information about the conditions on Earth during its deep history that we can't get any other way.

Distinguishing a meteorite from an Earth rock isn't easy. Fresh falls often have a characteristic crust, their surfaces burnished to a shine during their passage through the atmosphere. Some are truly beautiful. But many, let's face it, just look like rocks. The best way to decisively identify a meteorite is to delve into its chemistry. Large amounts of elements that are rare on Earth, such as nickel or iridium, are the surest sign of extraterrestrial origins.

Ancient impacts

Schmitz's interest in meteorites took hold as a young scientist when he spent time working in the US with Luis and Walter Alvarez. The father and son hypothesised that a huge asteroid had smashed into Earth 66 million years ago, snuffing out the dinosaurs and nearly all other life. They never found any fragments of the meteorite, just a layer of iridium distributed throughout rocks of this age the world over, presumably leftover from when the meteorite vaporised on impact. But what really caught Schmitz's attention was the idea that events in space could affect the course of Earth's history. The Alvarez duo had identified one point of influence. Were there others?

To find out, Schmitz wanted to discover some proper fossil meteorites. When he returned home to Sweden in the early 1990s, there were barely any known to science. Then one day Schmitz, who now works at Lund University, read a newspaper report about an amateur geologist named Mario Tassinari, who had found a few fossil meteorites in a quarry on the southern shore of Lake Vänern, Sweden. He and Tassinari soon agreed to collaborate on a study of the quarry. It wasn't difficult – the quarry workers cut out slabs of rock systematically to turn them into floor tiles. Schmitz and Tassinari simply asked the team to call them any time they came across a slab with an imperfection. About four times a year for the next few years, the workers would find a black smudge in the rock that turned out to be an ancient meteorite.

It seems that the limestone in this particular quarry was created in a way that was uniquely suited to preserving ancient meteorites. It formed very slowly, allowing time for meteorites to accumulate and be locked away. Schmitz investigated other quarries, but he hasn't found any others quite like this one. Eventually, he got the idea of going hunting in places where tiles from this quarry had been used to make floors. This is what led him to crawl around on his knees in public buildings across Europe. But, for a long time, his finds all came from freshly quarried rock.

By the early 2000s, Schmitz had more than 40 fossil meteorites. He began to think that this was a lot. When he did the sums, it seemed like there must have been a significantly greater influx of meteorites hitting Earth when this rock formed than there is today, which seemed odd. But with a sample size of just a few dozen meteorites, it was hard to be sure. He needed more – and he had a plan to get them.

Schmitz's proposal relied on the fact that, while large meteorites are incredibly rare, they become increasingly common the smaller they are. When you get down to tiny particles of space dust, there are a huge number of them. We estimate that nowadays Earth is sprinkled with about 100 tonnes of micrometeorites – extraterrestrial dust particles less than 1 millimetre wide – every year.

Finding these specks in ancient limestone was a huge challenge. Schmitz's idea was to look for an extremely hardy mineral found in meteorites called chromite. He reasoned that he could use strong acids to dissolve chunks of limestone from the quarry and that practically

GRAHAM CARTER

indestructible motes of chromite would be left behind. By 2003, he had used this method to harvest just over 500 extraterrestrial chromite grains from the quarry rock that had been formed during a period called the Ordovician, which began between about 485 and 490 million years ago. He looked at the numbers of sizeable meteorites and chromite grains in this rock and found that, in one small section, the frequency of both shot up massively. It was strong evidence that, for about 1 or 2 million years, Earth was subject to a rain of space rocks that was 100 times more intense than usual.

An epic collision

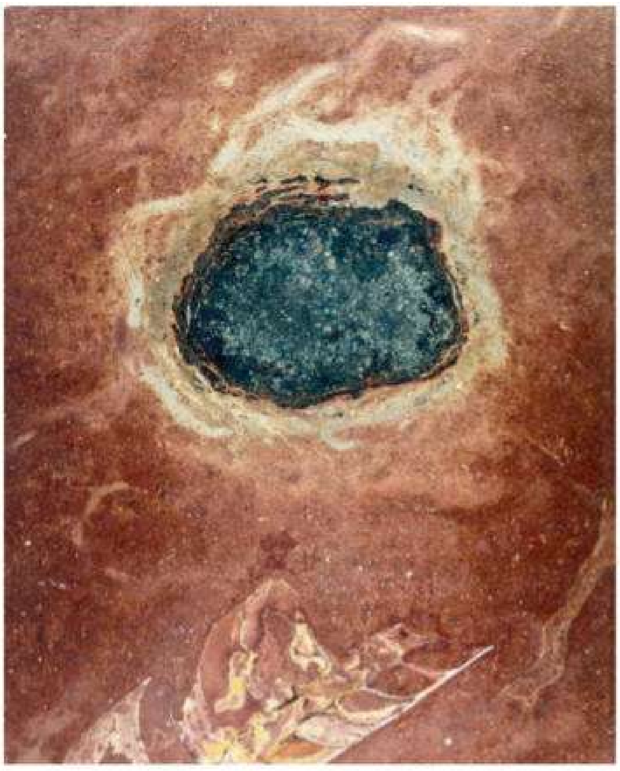
What was going on? Schmitz's best explanation is that this uptick was caused by an incident known as the L-chondrite parent body break-up event. This was a massive collision between rocks in the asteroid belt beyond Mars probably involving one huge asteroid, which is thought to be the source of many of the meteorites that land on Earth to this day. It must have been truly epic, releasing great tides of dust and rock into the inner solar system.

At the same time, Earth was experiencing an evolutionary turning point to rival the extinction of the dinosaurs: the Great Ordovician Biodiversification Event (GOBE). Just over 500 million years ago, the progress of evolution seemed to stutter before exploding again at top speed, producing a plethora of new species. Schmitz's hypothesis was that the break-up of that massive asteroid had increased the number of meteorites hitting Earth, which could have caused localised extinctions. With ecological niches left vacant, life spilled over again to fill them. It was a wild idea, but if he could prove it, this would be a second example of events in space influencing Earth's history.

Meanwhile, other scattered reports of fossil micrometeorites were beginning to appear in scientific papers. These were often just a few chance finds, nothing like the quantities Schmitz was dealing with. But the whispers of thesediscoveries reached Andy Tomkins at Monash University in Melbourne, Australia, and it aroused his competitive spirit. "I wanted to find the oldest ones," he says. He is based just a short flight away from Pilbara, home of Earth's oldest known rocks, on the other side of Australia. It was surely worth a try.

In 2014, Tomkins and his colleague Lara Bowlt, then also at Monash University, flew to Port Hedland on the coast of Western Australia, rented a four-wheel-drive vehicle and drove south into the desert. Eventually, the road ran out and they motored along a dry riverbed, then hiked the last few kilometres to the Tumbiana Formation, an area of rock that formed about 2.7 billion years ago. "It's beautiful, rugged country," says Tomkins.

These rocks are known for their pristine stromatolites, formations produced when layers of ancient bacteria grew. They are the oldest evidence we have for living microorganisms. "Any micrometeorites would have been raining down on an ancient, shallow sea, with the stromatolites getting all these extra nutrients from space added to them," says Tomkins. There was no guarantee they would find anything. But Tomkins and Bowlt dug out about 10 kilograms of limestone blocks and had them shipped back to Melbourne.



BIRGER SCHMITZ

Fossil meteorites, like this one in limestone, are teaching us about Earth's past

There, they cut the rocks into cubes, dissolved them in acid and sifted through the insoluble remnants with magnets and sieves. They ended up with 60 iron micrometeorites. That these were extraterrestrial was apparent from the presence of an iron oxide-based mineral called wüstite, which can only form at the extreme temperatures produced when these rocks sear through the atmosphere.

These were, by far, the oldest meteorites ever found – and Tomkins realised they were remarkable for more than just their age. Picture a shooting star streaking across the sky. It flashes hot and bright at first as it smashes into Earth's atmosphere at top speed, but then quickly slows. Tomkins realised the iron oxide in these meteorites must have formed in that brief period of initial heating, and so it captured oxygen atoms then and there. "It was the first time anyone had thought of a way to sample the upper atmosphere back in time," says Tomkins.

"These meteorites represent a part of the atmosphere we would otherwise have no way to look at – it's lost to time"

The scientific consensus has long been that Earth's atmosphere contained essentially zero oxygen until 2.4 billion years ago. But Tomkins and Bowlt's fossil meteorites seemed to show that this wasn't true. To account for the formation of the iron oxide, he and his team calculated that the upper atmosphere must have been about 25 per cent oxygen. There could have been a layer of haze that prevented the upper and lower parts of the atmosphere from mixing, meaning that any early oxygen wouldn't necessarily have been available to life on the ground. Still, it was a startling discovery.

Rebecca Payne at Pennsylvania State University agreed that Tomkins and Bowlt found genuine fossil meteorites, but she wondered if it was really oxygen that had been responsible for creating the iron oxide. Couldn't the oxygen have come from other sources, like carbon dioxide? Payne and her colleagues used computer modelling and experiments to investigate, and showed that if the upper atmosphere contained about

BIRGER SCHMITZ

Many fossil meteorites have been found in quarries lke this one

25 per cent CO_2, it could have oxidised the molten iron in the way Tomkins thought oxygen had.

Tomkins now accepts that Payne is probably right. But that doesn't diminish what he is excited about, which is using fossil meteorites as a means to probe the past. Payne is on the same page. "These meteorites represent a part of the atmosphere that we would otherwise have no way to look at – it's lost to time," she says. "It's now a question of finding more."

That is exactly what Martin Suttle wanted to do. In 2014, Suttle was studying for his PhD and decided to try fossil meteorite hunting in his spare time. One day, he found some lumps of exposed limestone on a roadside near his parents' home in Surrey, UK. The rock turned out to be 87 million years old. If there were meteorites inside, they would have fallen during the Cretaceous, the last days of the dinosaurs.

Suttle treated the rock in a similar way to Tomkins and retrieved 76 micrometeorites. Yet these tiny grains were very different from those found by Schmitz or Tomkins. They contained the sorts of iron-based minerals you would expect in a meteorite, but where the tell-tale nickel should have been, there was manganese instead.

Element swap

This was weird – except, when he thought about it, Suttle realised it made sense. The process of fossilisation often changes the composition of materials. Take dinosaur bones, which often aren't bones at all but minerals deposited in cavities where the bone used to be. Suttle realised that fossilisation could have swapped the nickel in the meteorites for manganese.

This was a game changer. Anyone looking through ancient sediments who came across particles like the ones Suttle found wouldn't have thought them to be extraterrestial because of the lack of nickel. "We have probably not recognised fossil micrometeorites that might have been found by other people in the past because this fossilisation process alters their chemistry," says Suttle. "We predict that they are quite a lot more common than is appreciated." Suttle is now leading a much wider study of fossil micrometeorites from ocean sediments in the collections of the Natural History Museum in London, and plans to use these to help reconstruct Earth's past climate.

For his part, Schmitz hasn't been idle. After his 2003 study, he built an industrial limestone-dissolving facility and had his team work its way through more than 1500 kilograms of the stuff, eventually amassing 900 chromite grains. His group also looked at 3000 micrometeorites found in ancient Antarctic sediments. Using both lines of evidence, he could pinpoint the sharp increase in cosmic dust flux to a specific period in the Ordovician.

Schmitz now thinks the effects of this increased flux went beyond the GOBE. He says the increasing amount of incoming dust in the atmosphere could have trigged, or at least exacerbated, the ice age known to have taken place at this time. "I think they've done a really good job of proving that there was a massive influx of extraterrestrial material around about that time," says cosmochemist Jemma Davidson at Arizona State University. "This certainly could have exacerbated the situation if there was already some cooling going on, in a runaway effect."

You might be wondering if Schmitz's search for fossil meteorites in floor tiles ever paid off. The answer is yes: in all his years of searching, he found precisely one. He won't reveal where it is, for fear of prompting too many visitors. All he will say is that it is in a small railway station in southern Sweden, hidden under a staircase. "The people who placed it obviously thought: 'This tile is ugly'," says Schmitz. "To them, it's a second-grade rock." ▮

Joshua Howgego is a feature editor at *New Scientist*

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Puzzles
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Tom Gauld for *New Scientist*
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Feedback
A boating walrus and weather odds: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Citizen science

Fight the plastic pandemic

Help researchers track the global effects of covid-19 plastic litter on wildlife, says **Layal Liverpool**

Layal Liverpool is a science journalist based in Berlin. She believes everyone can be a scientist, including you. @layallivs

What you need

Access to the Covid Litter website
A smartphone or camera

Citizen science appears every four weeks

Next week

Science of cooking

THE covid-19 pandemic has changed the litter we generate. Increased use of personal protective equipment (PPE) has added to a pandemic of plastic pollution, particularly medical face masks. Now, researchers are investigating how this wave of "covid litter" is affecting wildlife – and they need your help.

The Covid Litter project is calling on volunteers worldwide to record observations and submit photographs or videos of animals they see interacting with PPE litter – for instance, carrying the litter, playing with it, being trapped in it or using it as nesting material. You can submit your observations at covidlitter.com.

As well as photographs or videos, you can share information on the species you observed, the type of PPE litter (face mask or glove) and the nature of the interaction, as well as the date and location. The data will help researchers build a global picture of the impact that PPE litter is having on animals.

Auke-Florian Hiemstra (pictured) at the Naturalis Biodiversity Centre in Leiden and Liselotte Rambonnet at Leiden University, both in the Netherlands, started the Covid Litter project after a volunteer in a weekly clean-up they organise in Leiden discovered a fish trapped inside a glove in the water. That's when we realised that PPE litter can be dangerous, says Hiemstra.

HIELCO KUIPERS/NATURALIS

Since then, they have gathered many more examples of animals interacting with PPE litter, including a baby seal rescued by volunteers at the non-profit organisation Ocean Conservation Namibia that was found entangled in a face mask, as well as several observations of birds, such as coots in the Netherlands, using face masks as nesting material and becoming entangled in the straps.

"If I were a coot, I would also lay my egg on a face mask, because it's soft, it's a little bit like a small bed," says Hiemstra. "However, when the hatchlings come out of their eggs and the young are walking around, the chances of entanglement are very high."

Another problem is ingestion. "This happened with a penguin found on a beach in Brazil," says Rambonnet. Dissection at the Argonauta Institute for Coastal and Marine Conservation in São Paulo, Brazil, in September 2020 revealed that the penguin had ingested a face mask, which is probably what killed it, she says.

Now, says Rambonnet, they want bird photographers, bird spotters, rescue centres, vets and citizens to share observations. The pair hope the Covid Litter project will raise awareness about the harm PPE litter, and plastic in general, causes wildlife.

"I think our relationship with plastic materials should change," says Hiemstra. "Not viewing it as a single-use throwaway, but valuing it as a product that can last for 400 years and is really harmful in the wrong place." ▮

These articles are posted each week at newscientist.com/maker

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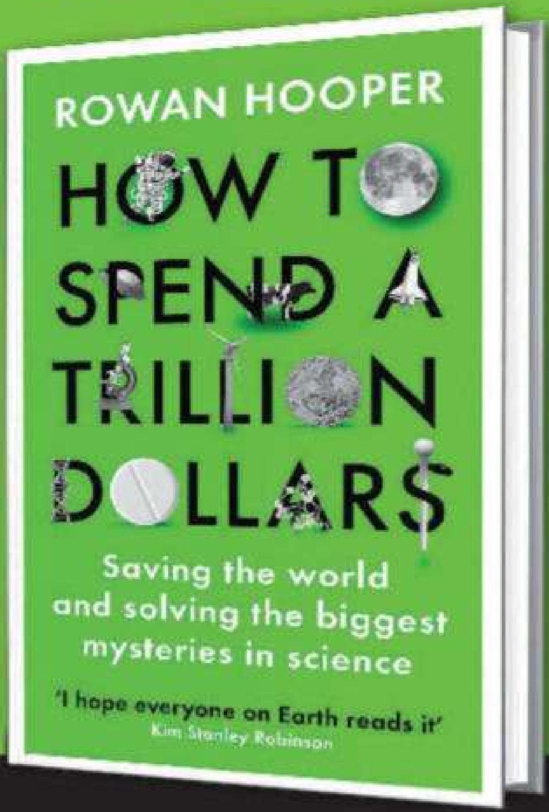
PHILIP PULLMAN



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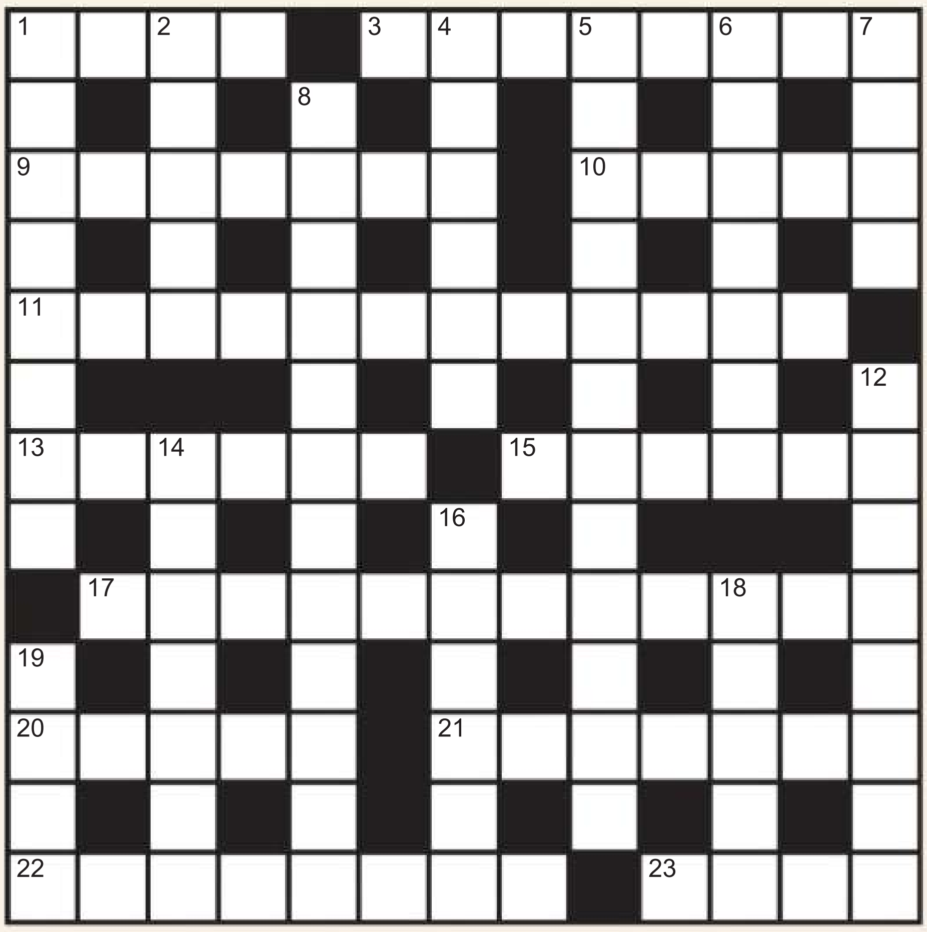
Cryptic crossword #64 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Joke lacking a good digital image format (4)
3 Likely in favour of tot eating piece of licorice (8)
9 Social climber sour following increases (7)
10 First off, frame taxonomic category (5)
11 Unfortunately designated me "no longer attractive" (12)
13 Not exactly flatbread, per follower (6)
15 Sell bicycle part, reportedly (6)
17 Persistently question family's requirements after losing initial gourd's contents (7,5)
20 Backing up, reached irrational speeds (5)
21 Star without agency? (7)
22 Alan Moore work recalled novel describing poor match (8)
23 Zoologist's device component flipped (4)

DOWN

1 Yes, and in Germany, treat condition common in infants (8)
2 Julep sometimes includes type of salts (5)
4 For example, terrier judge maintains tension (6)
5 Important variety routine including ten loons, for example, heading to York (12)
6 Maintaining density, take the top off unruly hairdo (7)
7 Lawn length (4)
8 Finally apprehended mug grabbing anything comic at hotel (6,2,4)
12 Spinning kitchen tool incorporates outwardly motionless night-time phase (3,5)
14 Drop Captain Von Trapp portrayer taking time for run (7)
16 No-name funds future groom (6)
18 Something hot used in Camembert (5)
19 Draw behind small pack (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #115

1 In what year did the Scopes Monkey Trial, concerning the teaching of evolution in Tennessee schools, take place?

2 Where in the body would you find Reissner's membrane?

3 Which gas did Joseph Priestley famously dub "dephlogisticated air"?

4 Who invented the multiwire proportional chamber, a type of particle detector?

5 Which 1994 NASA mission saw the first US spacecraft launched to the moon in more than 20 years?

Answers on page 55

Puzzle

set by Barry Clarke

#127 Brahms and Liszt

	First name	Surname	Composer
1	Agnes	Flop	Khachaturian
2	Bjorn	Grump	Liszt
3	Claudio	Hobble	Mozart
4	Dolores	Iddyhat	Prokofiev
5	Edgar	Jabber	Schubert

At the International Pianist Competition, the judge has made a list of the top five contestants together with the composers they played. However, still recovering from a heavy night on the town, he has made a howling error.

Although each item is in the correct column, he has only managed to get one item correctly positioned in each column. The following facts are true about the correct order:

1) Edgar is one place after Iddyhat.
2) Jabber is one place before Prokofiev.
3) Khachaturian is one place before Hobble who is two places after Claudio.
4) Agnes is two places before Schubert.

Can you find the correct first name, surname and composer for each position?

Solution next week

Bright and early

I am an early riser and am convinced that the day often starts off bright and clear, and gets cloudy by the time most people get up, in the south-east of the UK at least. Is that true, and if so why?

Talia Morris
Cape Tribulation, Queensland, Australia

Here at the Cape Tribulation Tropical Research Station in the Daintree rainforest in the far north of Queensland, we have been analysing local cloud cover data to determine how average daily solar energy input, known as insolation, has varied over the past 15 years or so.

Some of the readings were taken at half-hourly intervals and do indeed indicate that there is often a bright period around 6 to 8 am before the clouds move in.

We aren't sure why. It probably isn't due to shifts in relative humidity, as that remains fairly constant at between 85 to 95 per cent.

AGEFOTOSTOCK/ALAMY

Other than us perceiving it, how can we really be sure that time exists?

This week's new questions

The existence of time **Aside from our perception, how can we know that time exists?** ***Laura Istrate****, Bucharest, Romania*

Feeling flush **Are perimenopausal hot flushes just a side effect of changing hormones or are there possible evolutionary advantages to them?** ***Anna Wilson****, Central Victoria, Australia*

> "I have only seen really clear blue skies over London when flights were suspended due to the Eyjafjallajökull eruption in Iceland"

Jackie Jones
Brighton, UK

The day often starts bright and then gets cloudy here on the south coast of the UK.

I am painting a ceiling dial in a south-facing room. This involves a small mirror placed horizontally on the window ledge from which a spot of sunlight is reflected onto the ceiling. Obviously, it moves during the day and I mark where it is on the hour. I have many more dots for 8 and 9 am than for times later in the day, due to clouds obscuring the sunlight. At the end of the year, I will join up the dots to create hour lines across the ceiling.

As to why it is brighter earlier, I assumed it was associated with the early sun evaporating sea water to create clouds.

@policyscience*, via Twitter*

Heat and evaporation mean more moisture in the clouds and atmosphere. Living in Florida, I see this all the time. Most storms come in after noon, when clouds formed over warm ocean roll in.

David Gordon
Leeds, UK

This is part of the phenomenon known as "British weather", an affliction also prevailing in the north of the country. Being encircled by water, the UK is surrounded by moist air that is drawn inland by the convection-induced pressure gradient initiated by the sun warming our land mass.

John Middleton
Leominster, Herefordshire, UK

I used to be a commercial pilot and flew through the busy airspace above south-east UK. I, too, noticed that the sky was clearer earlier in the morning, particularly in stable high pressure air in summer.

There is very little commercial air traffic overnight, so to maximise aircraft utilisation, many flights start in the early morning. The crystal-clear early morning skies seen on outbound flights were often replaced by hazy overcast ones on the return leg. This was the result of the dispersion of persistent contrails from aircraft.

The trails are created by the water vapour in the exhaust gases turning into ice crystals, with 2 tonnes of water vapour produced for each tonne of fuel burned. These then evaporated overnight. Being lighter on the return leg, we could fly higher and look down into the murk.

Simon Evans
Malvern, Worcestershire, UK

While camping along the south-west coast of France, it was noticeable how a clear early morning sky would become hazy by mid-morning. This was due to the vapour trails from the passenger jets going west spreading out and merging.

Ian Johnstone
Melbourne, Australia

Travelling to Heathrow airport near London for early morning flights, I have noticed the pattern of contrails spreading across an otherwise blue sky. Within 30 minutes, these discrete trails had dissipated into a general blur. By mid-morning, the whole sky was hazy.

The only time in 17 years of living in London that I saw really clear blue skies was in 2010 when all flights were suspended due to the eruption of Iceland's Eyjafjallajökull volcano.

@#chrisl4m*, via Twitter*

Is this a meteorological question or a metaphysical one?

Superstitious creatures

What is the evolutionary reason that we and other animals such as orangutans and pigeons display superstitious behaviour?

@abek42*, via Twitter*

Superstition is rooted in a mismatched correlation between cause and effect.

Anne Barnfield
London, Ontario, Canada

A superstition is an irrational belief that can lead to the

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Tom Gauld

for New Scientist

DO YOU EVER FEEL LIKE WE'RE BEING OBSERVED BY ANOTHER LIFE FORM?
DO YOU EVER FEEL LIKE WE'RE BEING OBSERVED BY ANOTHER LIFE FORM?
DO YOU EVER FEEL LIKE WE'RE BEING OBSERVED BY ANOTHER LIFE FORM?

performance of various rituals. These can be explained by operant conditioning principles, where a chance occurrence is linked with a positive outcome, which then increases the likelihood of repeating the behaviour.

The psychologist B. F. Skinner discovered many of the functions of this reinforcement via a food system for pigeons in his laboratory. Skinner found that even with regular reinforcements some of the pigeons developed odd behaviours such as turning around or going into a particular corner, then returning to face the food dispenser expectantly.

A coincidental reinforcement had led to the random behaviour becoming a fixed response. These findings were reported in a 1948 paper titled "'Superstition' in the pigeon".

Humans are even more likely to develop superstitions due to our tendencies to cognitive fallacies such as confirmation bias, where we tend to interpret outcomes in line with our pre-existing beliefs.

> **"The development of odd behaviours in lab subjects was reported in a paper about superstition in the pigeon"**

A lecture I give as part of a psychology applied to sport course explains this situation to students, many of whom are involved in sporting activities and may engage in such behaviours.

In any sport, by chance, an action could lead to a point or goal a certain percentage of the time. Activities which, in the past, had been followed by a positive outcome (for example, a goalkeeper touching the goalposts and then making a save) are likely to be repeated – not because they actually have any effect, but simply because of the coincidental reinforcement.

@Madzepeda123, *via Twitter*
Intermittent rewards coupled with the brain's pattern-recognition function create an internal feedback cycle. The brain's need to impose order on nature is critical.

Tom Allaway
Goulais River, Ontario, Canada
A cognitive bias to perceive patterns and causal connections is a useful heuristic in discovering actual connections in the real world. The potential cost of errors is presumably outweighed by the benefits of discovery.

@AndyTinlin, *via Twitter*
Daniel Dennett explains this in his book *Breaking the Spell*, showing how an assumption of agency in natural phenomena led to better evolutionary outcomes. If there's a rustle in a hedgerow, it is better to assume it's a threat than not.

@Pillownaut
via Twitter
Ritual is psychologically comforting in the face of the unknown.

Answers

Quick quiz #115

Answers

1 1925
2 The inner ear. It is also known as the vestibular membrane or wall
3 Oxygen
4 Georges Charpak
5 Clementine

Quick crossword #89

Answers

ACROSS 8 Coma, **9/13** Wendy Lawrence, **10** Iron, **11** Mantid, **12** Avian flu, **15** Dilate, **17** Bivalve, **19** Prussic, **22** Gneiss, **24** Hackable, **26** Hay fever, **28** Nodule, **30** Zinc, **31** Ulnar, **32** UFOs

DOWN 1 Iota, **2** Bacteria, **3** Sweden, **4** Inhaler, **5**Cylinder, **6** Signal, **7** Soil, **14** Alien, **16** Trial, **18** Vesuvius, **20** Scandium, **21** Pharynx, **23** In fact, **25** Canary, **27** Acid, **29** Loop

---

#126 More chocs-a-weigh

Solution

6.5 kilograms will weigh up to 32 chocolate bars. If we label the machines A, B, C, D and E, Hazel can put one bar from A on the scales, two from B, and 4, 8 and 16 from C, D and E, totalling 31.

If perfect, the bars would weigh 31x200 grams = 6.2 kilograms in total, so the shortfall below 6200g divided by 5(grams) gives the number of defective bars.

There is only one way to make this number using 1, 2 , 4, 8 and 16. For example if the shortfall is 70g, divide by 5 to yield 14, and that can only be made up as 2 + 4 + 8. This corresponds to machines B, C and D at fault. This allows Hazel to determine the machines at fault with a single weighing.

Flipping out

There are two fish in a tank and one says to the other: "How do you drive this thing?" The oldest ones are the… oldest, and in all honesty we're only tangentially reminded of this one by the latest twist in the saga of Wally the walrus.

Wally was first seen off the coast of Ireland in March, with marine biologists speculating that he had fallen asleep on an iceberg that became untethered from its Arctic moorings. In flagrant breach of travel restrictions, he has since been spotted off Wales, Cornwall in the UK and France, and set a record for the most southerly walrus by popping up near Bilbao in northern Spain. Nice work if you can get it.

Not that the peripatetic pinniped has always been welcome. His stop in the Isles of Scilly off Cornwall in July coincided with a spate of pleasure boats sunk as Wally tried to climb aboard. To that we can only say, if you will make them white and shiny what do you expect.

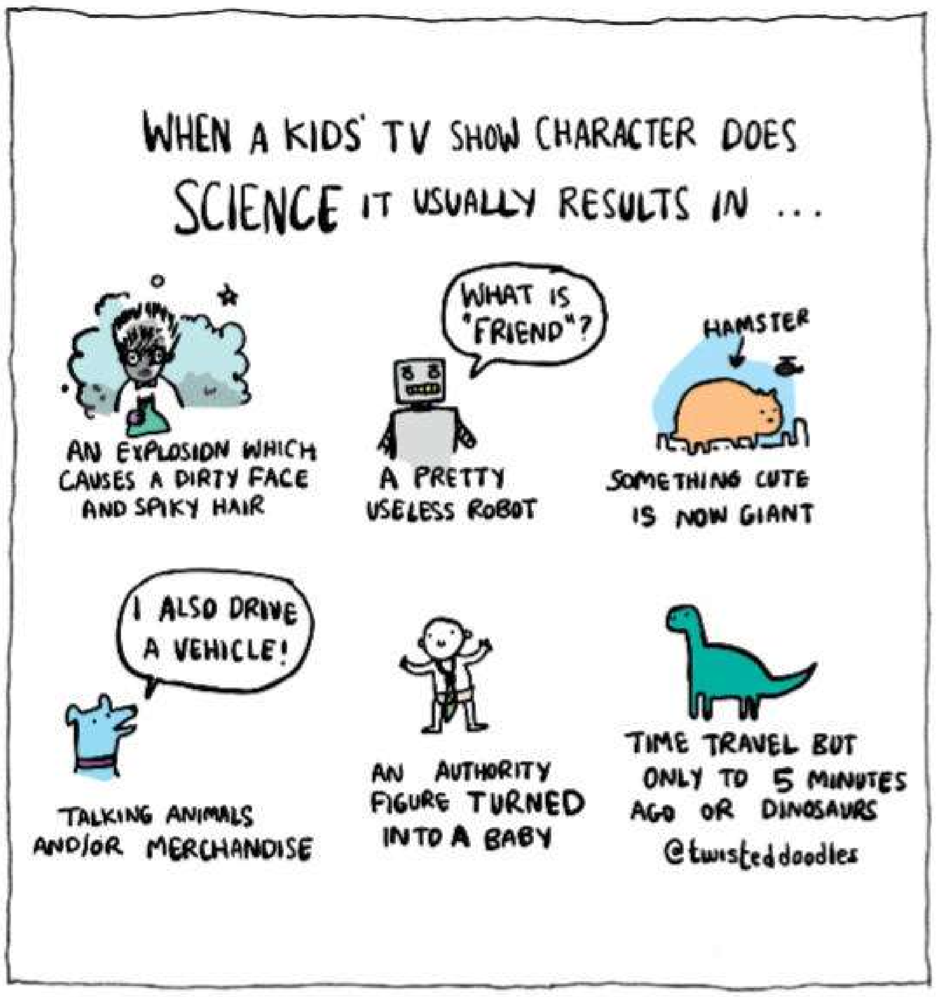
An effort to scare Wally off using polar bear scent and growls now appears to have worked, as he reappeared in County Cork, Ireland, lounging on a motorboat belonging to a gin distillery. Heart-warming stuff, and we hope he is taking advantage of the facilities. Now, how do you drive this thing?

To the nth degree

Possibly too much in the right place is Harry Parkes from London. He relates recently picking up a passenger at the city's Heathrow Airport. This traveller had booked a coronavirus test at a centre whose website supplied GPS coordinates accurate to 16 decimal places in longitude and 14 in latitude. "To my calculations, the location of the testing centre is given to within the size of an atom," he says.

Whether the super-accurate coordinates made the test centre easy to find, or its minuscule dimensions made it rather more complicated, he doesn't say. But we agree it would be a fine thing if we could guarantee the tests themselves were that accurate.

Twisteddoodles *for New Scientist*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WHAT IS "FRIEND"?
A PRETTY USELESS ROBOT
HAMSTER
SOMETHING CUTE IS NOW GIANT
I ALSO DRIVE A VEHICLE!
TALKING ANIMALS AND/OR MERCHANDISE
AN AUTHORITY FIGURE TURNED INTO A BABY
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@twisteddoodles

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Consideration of items sent in the post will be delayed

What are the odds

Several readers write in following last week's revelation that the Canadian government's weather service has a statistical hole, in so much as it doesn't allow a probability of precipitation between 40 and 59 per cent.

Paul Vann from Devon, UK, points out that BBC weather forecasts seem only to have wind speeds in single figures and in the 10s, 20s, 40s and 50s of mph, but not in the 30s. Our experience of the gusty Devon coast in winter suggests this hole doesn't exist in reality, so we would welcome counter-testimony on the forecast front.

Ken Lee from Stoke-on-Trent, Staffordshire, UK, meanwhile, recalls listening to the morning weather forecast when visiting the US city of Philadelphia in the 1980s. "When we heard, 'Probability of precipitation: 100 per cent', we assumed they meant, 'It is raining'," he writes.

Likewise, we interpret the delicious formulation used on the BBC's much-loved shipping forecast, "precipitation within sight" as "it is raining, but over there".

We are also reminded of the ongoing conflict between advocates of two rival approaches to probability – the frequentist and the Bayesian – about the sense or nonsense of probabilities that express not pure randomness, but individual ignorance about what's going on.

If the probability of rain is 50 per cent and it turns out to be actually raining, what is the probability that it is raining?

To the max

Approaching numbers from an entirely different angle, and enriching us culturally in the process, is Gerben Wierda from Heerlen in the Netherlands. When looking for an office chair, he recently came across one with the specification "Belastbaar tot minimaal 110 kg", which translates to it carrying a maximum weight to a minimum of 110 kilograms.

Our logic module having just overheated, we're unable quite to work out whether that means it carries only weights above 110 kilograms, no weight at all, or something else entirely. Caveat emptor, as they say, or at least they did in the Netherlands a while back.

Looking backwards

Hilary Johnston regrets that in our recent determination to see the world from different perspectives (17 July and 31 July), we didn't mention the age of our correspondent who tried to clean the chocolate off the seat of his trousers in front of a mirror.

"As an octogenarian, I would suggest an interesting experiment for those with as many wrinkles as I have. With your back to a full-length mirror, bend down and look at yourself through your legs," he writes – to which we would add, please, only if you can. By reversing the normal skin-stretching effects of gravity, you may not recognise yourself, he promises.

In a similar vein, John Evans recommends the experiment of lying on your back in an open space such as a field or beach, tilting your head backwards and moving it from side to side to see an Earth that's not flat, or even expectedly convex, but resolutely concave.

Definitely one for the conspiracy theorists. Thank you, John, too, for your self-effacing addendum: "I had a letter in the NS years ago, around late October/early November 1984, but might be worth a mention again". Twice in four decades? Now that's demanding. ▮

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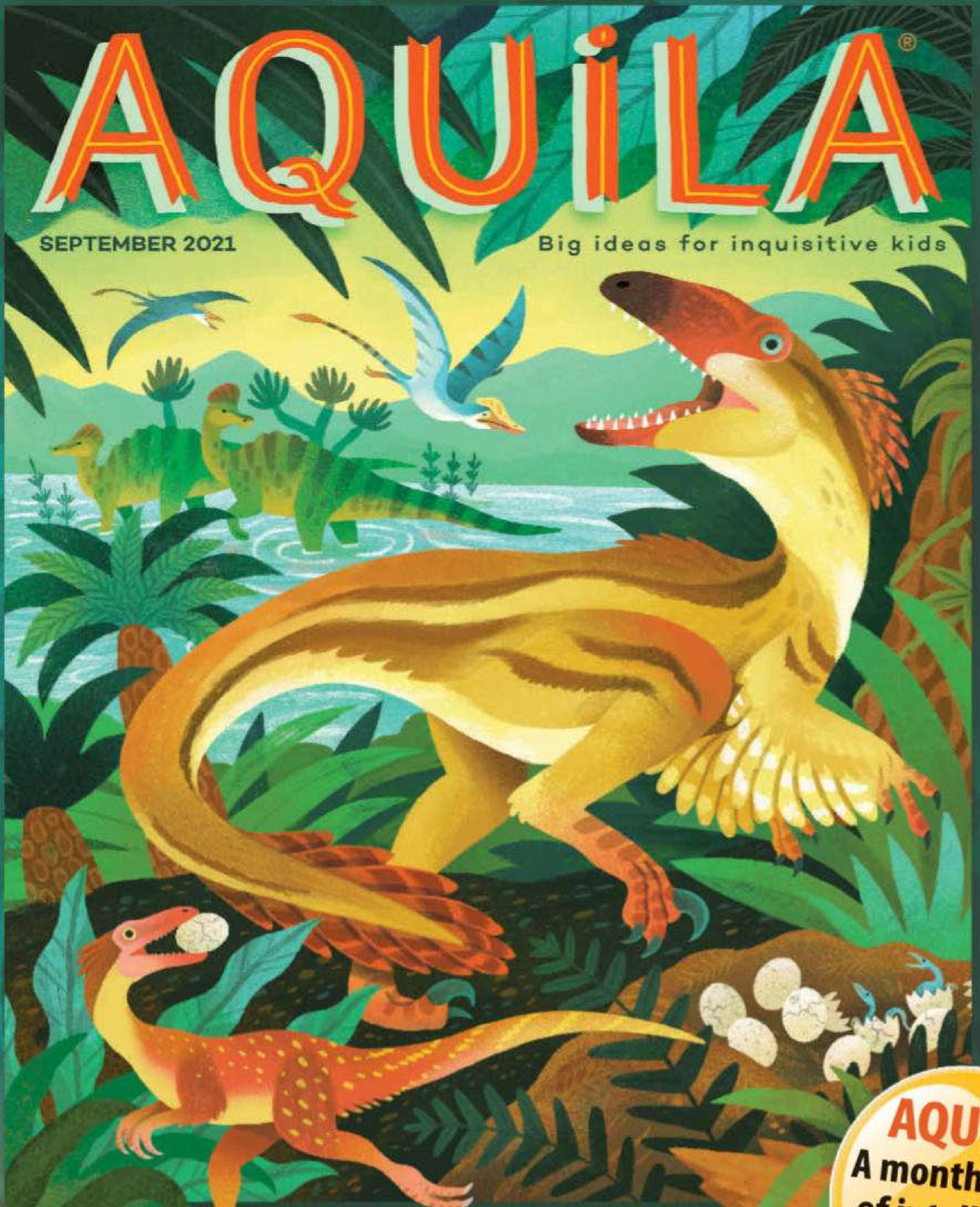

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